Shell Exploration and Production

Shell

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Ms. Kate Kelly
Director of Air, Waste, and Toxics
Environmental Protection Agency, Region 10
1200 6th Avenue, Suite 900
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January 11, 2013

Re: Shell Gulf of Mexico Inc.
Noble Discoverer – Chukchi Sea
Application to Revise OCS PSD Permit to Construct No. R10OCS/PSD-AK-09-01

Shell Exploration and Production received your letter of December 31, 2012 that identified supplemental information EPA requires before our November 29, 2012 permit revision application will be deemed complete. Although all the requested information has been previously provided verbally or by email, this letter provides that information with the required certification.

Based on information and belief formed after reasonable inquiry, I certify that the statements and information in this submission are true, accurate, and complete.

Please contact Pauline Ruddy (907-771-7243) or Chris Lindsey (907-771-7262) if you have any questions.

Susan Childs
Alaska Venture Support Integrator, Manager

Enclosure: *1) Response to December 31, 2012 Request for Additional Information*
2) Flash drive of electronic records

cc: Chris Lindsey, Shell
Pauline Ruddy, Shell
Lance Tolson, Shell
Natasha Greaves, EPA Region 10

Attachment: Response to December 31, 2012 Request for Additional Information

Best Available Control Technology (BACT) Documentation Issues

1. Page 31. Data and analysis supporting the statements made regarding the portion of Discoverer main generator deviation time which is attributable to operational problems with the E-PODS.

Page 31 of the November revision application states that "As a result of these measures, continuous monitoring data from E-PODs installed on FD-1
through FD-6 showed that 15-min deviations attributable to the issues discussed in Section 1.6.1 decreased from 3.5 percent in September to 1.1 percent in October, of the total time that the main generator engines operated in each month.

Over the course of the 2012 drilling season the E-PODs installed on units FD-1 though FD-6 recorded a number of 15-minute periods where the control systems operated outside the permit specified operating ranges. As such, Shell recorded these permit deviations and submitted permit deviation reports as required. Each 15-minute period was categorized based on the root cause of the deviation. The categories include engine start-up/shutdown, spurious data while the engine was off, low engine load, and equipment malfunction.

The statement on Page 31 (above) conditions that the percentages are specific to the issues addressed in Section 1.6 of the application which center on operational realities of the arctic affecting the E-POD systems and inherent low load operation due to the engine capacity limitations and type of operation (listed in Section 1.6.1). Therefore, permit deviations due to engine startup/
shut-down, which are addressed in Section 6 of the application, and deviations due to spurious data while the engines are off are not included in these calculations. Additionally, permit deviations due to equipment malfunction that are not related to the issues addressed in Section 1.6.1 and are one-off malfunctions that would require submission of a deviation report regardless of any of the revisions and operational improvements proposed by Shell are not included in the calculations that determined the above percentages.

Thus, four 15-minute periods during which intermittent communication errors prevented the E-POD system installed on FD-6 from recording temperature data on October 5, 2012 are not included in the calculation. Additionally, the calculations do not include forty-two 15-minute periods when there was a power loss to the E-POD system installed on FD-4 on September 6 and 7, 2012. These forty-two 15-minute periods were reported to EPA within an excess emission report submitted on September 9, 2012, and were therefore reported as „R"deviations in the consolidated permit deviation report submitted for the month of September, where „R" stands for "Refer to previously submitted Excess Emission Report for this date and source." Shell discontinued the naming of deviations as R within the consolidated permit deviation report for the month of October in order to be clearer as to the root cause of each deviation listed.

Thus, the percentages presented on page 31 of the permit application include 15-minute periods during which low-load operations or equipment malfunction, such as the presence of urea crystallization, led to deviations from permit specified operating conditions. The percentages are calculated by summing all the relevant 15-minute deviation periods and dividing that value by the total time the units FD-1 through FD-6 operated, specific to each month. The first tab of the attached spreadsheet summarizes the critical information from the additional tabs and presents the percentage calculations.

After his review of this analysis and the included the calculation details, EPA's Zach Hedgpeth asked us to provide the full set of data, as well as any analysis and screening steps that were performed, that led to the statements made regarding the percentage of FD-1 through FD-6 operational time spent as deviations caused by the issues raised in section 1.6 of the November 28 application. Therefore, the follow-up response includes all 15-min data recorded by the E-PODs installed on units FD-1 through FD-6 throughout the 2012 drilling season and the screening performed that determined which periods were deviations. Additionally, the response includes a description of how both 5-min and 15-min E-POD data were analyzed, based on engine temperature, urea flow, electrical output, and fuel use, to determine the cause of each identified period of deviation.

On the enclosed flash drive is a spreadsheet titled "1. Discoverer2012-MainGenDeviations.xlsx" that provides the pertinent data and calculations supporting this response. The full set of 15-min data (for units FD-1 through FD-6) and the initial screening performed is provided in spreadsheets "2012-09-DiscoTempUreaDevFullData_r1-FD-1-6.xlsx" and "2012-10-DiscoTempUreaDevFullData-FD1-6.xlsx" for the months of September 2012 and October 2012, respectively. A description of how data was analyzed to determine the cause of each deviation is provided in "Cause Category Determinations.pdf". The above description discusses how parametric behavior in 5-min increments was reviewed as part of the cause categorization process. The 5-min data is provided in the spreadsheet "7. Discoverer Main Generator Data.xlsx" which is referenced by several sections of this response letter.

2. Pages 33-41. Data and analysis providing the basis for the requested NOx BACT limits. This should include the data and calculations showing how Shell screened the data, estimated emissions, and developed the charts in the application.

The purpose of these plots was to illustrate the performance of the E-POD system in controlling NOx emissions during the 2012 drilling season. The Discoverer was a stationary source in the Arctic in 2012 during the following periods:

• From 9/6/2012 21:16 – 9/6/2012 21:52 (brief period during which anchor was being set) [0.6 hours as a stationary source]
• From 9/6/2012 22:14 – 9/10/2012 12:59 (Discoverer was moved for ice reasons on 9/10/12 and did not re-anchor until 9/21/2012) [86.75 hours as a stationary source]
• From 9/21/2012 10:25 – 9/21/2012 12:52 (brief anchor move) [2.45 hours as a stationary source]
• From 9/21/2012 @ 13:08 – 10/28/2012 @ 02:03 (Main Drilling Season) [804.9 hours]

The spreadsheet "CFDPlots.xlsx" was used to make the plots on pages 35-40 of the November 29 permit application. This original spreadsheet is provided on the enclosed flash drive, but as noted below, it has been replaced by a modified version of the spreadsheet based on subsequent requests from EPA. The following discussion applies to the original version of this spreadsheet.

The data used to create Figures 1-3 through 1-8 were taken from the main drilling effort beginning September 21, 2012. Data from the earlier periods were felt to be unrepresentative of good E-POD performance because problems with urea crystallization were still being addressed. For the purpose of creating the plots, the data from the period 9/22/2012 00:05 through 10/25/2012 00:00 were used with the exception that data from one day (9/27/2012) were not included in the original analysis. The data for this day are now included in slightly revised figures in the attached Excel file. The data used in the analysis includes 792 hours. The Discoverer was a stationary source of emissions for a total of 894.7
hours. The data used in the analysis represent over 88% of the time the Discoverer was a stationary source in 2012. These data were judged to be sufficiently complete and representative to illustrate the performance of the EPOD system in controlling NOx.

There are two sets of input data used to make these plots:

1. The raw data from the Continuous Monitoring System (CMS). The E-POD system has its own data recording system, but these data alone do not contain sufficient information to conduct the performance analysis. The ADM (automated data management) system polls the E-POD data system and other electronic-recording systems on the Discoverer and reports values every 5 minutes to the CMS system, which logs the information. Data were recorded for each of the 6 generators every 5 minutes. During the 33-day period for which data were available, there were 33 x 24 = 792 hours. In each hour there are 12 five-minute blocks, hence there are 792 x 12 = 9,504 5-minute blocks. For each five-minute block, five parameters of interest in the current evaluation were recorded by the CMS system for each of the six generators:
a. The date/time
b. The electrical power generation rate in kilowatts of electricity (kWe – sometimes written as ekW).
c. The exhaust temperature in Celsius
d. The NOx concentration in the inlet to the E-POD in parts per million (ppm)
e. The NOx concentration in the outlet from the E-POD in parts per million (ppm)

2. The stack test data for each of the six D399 generator engines. Only two parameters were used from these data; the average kWe during the test, and the average exhaust flow rate expressed in dry standard cubic feet per minute (dscfm).

All of these input data are provided in the spreadsheet "CFDPlots.xlsx". The CMS data were provided to ENVIRON by Mr. Jim Peltier in an email to Eric Hansen of ENVIRON, dated November 5, 2012. Mr. Peltier is with Caterpillar CleanAIR Systems, and is Engineering Supervisor for the development of the E-POD systems. Mr. Peltier previously obtained the data from Shell operations personal and was evaluating the data for Caterpillar"s own assessment of the performance of the E-POD systems during the 2012 drilling season. ENVIRON spot-checked

the data from Mr. Peltier with the raw data in the E-POD data recorders themselves. Although the E-POD data recording system used a different time interval than the CMS system and there are some minor averaging or round-off differences, the spot checking showed the data obtained from Mr. Peltier were the same as the raw data from the E-POD data logger.

The stack test data were collected during the May 2012 emissions testing of emission unit FD-1 through FD-6 at Vigor Shipyard in Seattle, and were provided to EPA on July 27, 2012. A summary worksheet of just the D399 NOx emission test data is included in the "CFDPlots.xlsx" spreadsheet.

The purpose of the plots was to provide a cumulative frequency distribution of the emission factors observed during the drilling season. Using this method it is possible to determine the percentage of time emissions could be maintained below a specific emission rate, expressed in grams per kilowatt-hour (g/kW-hr).

The preparation of the figures involved the following analysis steps.

1. Prior to the drilling season, emission source tests were performed at different electrical generating rates (approximately 100%, 75% and 50%) for each generator engine. Each source test consisted of three runs and an average value of the electrical load in kWe and an average value of the calculated exhaust flow rate in dscfm was computed and is shown in the worksheet entitled "StackTestData." These three average values for power and flow were used in the worksheet "Flow-vs-kWe" to make plots of the flow as a function of the electrical power. Excel was used to generate a separate equation for each generator of the form $y = mx + b$, where y is the exhaust flow rate in dscfm, x is the electrical power in kWe and m and b are the linear regression values provided by Excel in the actual graph of the data. This step was necessary because the E-POD data include only a measurement of the NOx concentration in the exhaust, not a measurement of the actual mass emission rate of NOx, and flow is necessary to convert the concentration to a mass emission rate. Using the stack test data, ENVIRON was able to develop the equations that compute flow rate from electrical power, a parameter that was recorded by the E-PODs.

2. The raw data from the E-PODs are provided in shaded cells of the worksheets with titles such as "Raw Data Gen 1" or "Raw Data Gen 2" etc. Not all of these data are valid as is evident from the negative values reported for concentration or the very low values recorded for the electrical generation. It is thought that these represent times when the engine was either turned off or in the process of being shut down or started up. It was necessary to remove these invalid data to create the cumulative frequency plots. Accordingly, two criteria were used to determine if a particular data point was valid:
a. It must have an engine power greater than 10 kWe
b. It must have a positive inlet and outlet NOx concentration

3. In each of the six raw data worksheets, the data are classified as "Valid" or "Not Valid." Three of the columns, the date, the power level and the NOx ppm in the outlet stream are then hard

copied into columns L, M and N and sorted to remove all the Not Valid data and arranged by ascending date.

4. Columns O and P use the equations from the "Flow-vs-kWe" worksheet to compute the flow for each valid hour of data and by multiplying by the concentration of NOx, determine the flow rate of NOx gas in cubic feet per hour from the exhaust.

5. The ideal gas law is then used to convert the cubic feet of NOx per hour into lb-moles per hour. The ideal gas law is often represented as PV=nRT where P is the pressure, V is the volume, n is the number of moles of gas, T is the absolute temperature and R is the ideal gas constant which has different values, depending on the units selected for the other parameters. In this case, the units selected were cubic feet for the volume, atmospheres for the pressure, lb-moles for the molar number, and degrees Rankin for the temperature and the appropriate value of R in these units is 0.7302 ft^3-atm/lb-mol- R. Using the molecular weight of NO2 (as is customarily done for NOx) of 46.0055 lb/lb-mole, the emission rate in lb/hr is calculated in column T.

6. Finally, column U converts to grams per hour and column V calculates the emission factor by dividing the grams per hour by the kWe power level to determine the g/kW-hr.

7. The worksheet labeled "Valid" then simply references the date/time and g/kW-hr for each valid 5-minute data point from the 6 raw data sheets.

8. The worksheet entitled "Sequential" processes the data from the "Valid" worksheet. This worksheet places the data in sequential order, and marks all hours as to whether valid data are available or not. From the 5-minute data, rolling hourly averages and rolling 24-hour averages are calculated. In order to avoid sparse data from dominating the plot, 1-hour and 24-hour average were only computed if 75% of the 5-minute periods within that 1-hour or 24-hour period were available. Otherwise, the 1-hour or 24-hour rolling average is listed as "No Data". The 5-minute data, rolling hourly averages and rolling 24-hour averages are then hard copied and sorted to remove the "No Data" values. The data are sorted from low to high and percentage levels (fractions) computed based on the number of data points in each data set. These are then hard-copied again into the columns labeled "Data for Plotting" and the plots generated from these columns.

The final products are the plots in the workbook tabs labeled Gen1 Plot, Gen2 Plot, etc.

After his review of this analysis, EPA"s Zach Hedgpeth asked us to examine the effect on the cumulative frequency plots if we had used more exclusive screening criteria. Consequently, two additional screening criteria were added to the analysis. The first was to eliminate all cases where the exhaust temperature was below 300 degrees C. The second was to eliminate all cases where the urea flow rate was less than 2 liters per hour or greater than 20 liters per hour. A modified version of "7. Discoverer Main Generator Data-analysis.xlsx" is provided on the flash drive that shows a plot of urea flow rate versus temperature and highlights these new screening criteria with a thick blue line. This figure illustrates that these new screening criteria capture only times when the E-PODs were being used to control the NOx from the engines.

Mr. Hedgpeth also asked that we examine periods when deviation reports were submitted for the main generators to determine if the initial analysis might be including data in the cumulative frequency plots for periods when the generators were cited in a deviation report. We did that analysis and determined that the vast majority (487 of 505 deviation reports) are already eliminated from consideration with the screening criteria already being used.

On the enclosed flash drive are the initial and revised spreadsheets titled "7. Discoverer Main Generator Data-analysis.xlsx" and "CFDPlots.xlsx" that provides the data supporting this response.

3. Page 58. De-rating of the Nanuq main propulsion engines relies on a power-to-fuel consumption relationship. A hard copy of the spreadsheet is provided in Appendix H to the application. The Excel version of the spreadsheet is needed to facilitate examination of the calculations. The basis for the information used in the spreadsheet should be provided, including how power from the propulsion engines was measured and converted into kW.

The enclosed flash drive includes the spreadsheet "3. RS NanuqEmissions 20120806.xlsx" which provides the graphic presented in Appendix H. The loads were approximated from throttle position. N-1 and N-2 power levels were established by setting engine throttle (and propeller pitch in the case of variable pitch propulsion systems) at 25, 50, and 75, and 100 percent of full load. The engine throttle positions (and pitch) were maintained at appropriate levels for the duration of the particular test.

4. Pages 67-69. The data for exhaust gas temperature and fuel flow for the crane and cementing engines which forms the basis for the claim that catalytic diesel particulate filter (CDPF) is technically infeasible is needed. The pre-screened data submitted in Appendix I to the application is not sufficient because it is not possible to see how the data was screened. The data and analysis should demonstrate how the duty cycle precludes the engines from reaching operating temperature, and provide the basis for the increased hourly fuel consumption rate. The supporting calculations for Table 5-1 should be provided.

Supporting information for Table 5-1 of the November permit revision application is provided in the spreadsheet "4. CMS Compliance Monitoring Data_Disco_FD-14_FD_17_20121218.xlsx" found on the flash drive. Tabs FD-14, FD-15, FD-16, and FD-17 contain the 5-minute raw data for each of these emission units for the entire period of Oct 5, 2012 through Oct 28, 2012, which is the period Shell considers representative of the 2012 season operation. Tabs FD14&15_Temp>80 (cranes), and FD16&17_Temp>80 (cementing) contain the same data type for the respective emission units, but filtered for only the 5-minute periods when exhaust temperatures (column E) are greater than 80 Centigrade (C), using the built-in Excel filter. Shell defines an engine use "event" as a period of time when the exhaust temperature exceeded 80 degrees Centigrade, as discussed in the application.

The "use events" on tab FD14&15_Temp>80 are separated using thick lines, so that the first crane event is contained in rows 3 through 7, and the second event is contained in rows 8 through

38, and so on. The November application Table 5-1 stack temperature statistics are listed at the end of the FD-14 events, which is at row 2585, and for FD-15, at row 4329. These statistics are drawn from the data using standard Excel statistical functions.

Table 5-7 is built from the same spreadsheet, tab FD14&15_Temp>80. The fuel flow data (column D) are converted using stack test emission factors to 5-minute NOx emissions, and these are summed to provide the 1-hour NOx emissions, including the 8 reported exceedances shown in Table 5-7. The 8 exceedances are provided in boxes located in columns H and I. For example, the October 7 exceedance is provided in a box in rows 271 to 282. (The Oct 5 exceedance is grouped further down with the FD15 data since it is primarily due to FD15). All the calculation algorithms used are embedded in this spreadsheet.

A minimum fuel flow threshold value of 1.2 gallons per hour (0.1 gallons per 5-minute period) was used in the data processing during the season to eliminate meter instability during periods of very low to zero fuel flow. During the season, fuel consumption for all emission units was measured as the difference between fuel coming to the emission unit and the excess fuel returning to the fuel tank. When the overall fuel consumption was low, such as when a crane engine was idling, the fuel consumption was a small difference between two large fuel flow values (inflow vs. outflow). When the difference was below the 0.1 gal/5-minute threshold, the difference measurement oscillated between negative and positive numbers. To remove this instability, values below this threshold were defined as "0.0" gallons per hour for data processing purposes.

During review of this data, it was apparent that many of the 5-minute crane fuel flow values were below the meter minimum flow threshold. An additional analysis, therefore, was conducted to evaluate if the 1.2 gallon per hour threshold was not sufficiently conservative for emissions estimation purposes. The spreadsheet analysis of one-hour NOx emissions was reanalyzed by applying 0.4 gallons per hour as a new minimum threshold. Using this lower minimum threshold, the calculated NOx emissions for the eight crane exceedances increased less than 0.5 percent – an insignificant difference from calculations based on the 1.2 gallon threshold. Shell therefore believes that the approach taken during the season, using the 1.2 gallon per hour threshold, sufficiently estimated emissions and had no material effect on the resulting high 1-hour crane NOx emissions.

5. Pages 74-75. The basis for the cost numbers in Tables 5-3 and 5-5.

Please find attached "C. Garth – Crane replacement cost.pdf" that includes a November 9, 2012 email from Garth Pulkkinen with Noble to Rodger Steen with Air Sciences that provide the basis for Table 5-3 and also constitute the response to the reference request "C" listed below.

Please find attached "5. FW Cost Breakdown.pdf" that provides the costs used to create Table 5-5.

6. Page 77. The supporting calculations for Table 5-7.

Please refer to the spreadsheet "4. CMS Compliance Monitoring Data_Disco_FD-14_FD-17_20121218.xlsx" on the flash drive, which provides the supporting calculations for Table 5-7

7. Page 90. Data and analysis underlying the statements made regarding how long it takes the engines equipped with catalytic control devices to reach operating temperature.

Please refer to the spreadsheet "7. Discoverer Main Generator Data.xlsx" which provides the data to support the analysis.

8. In Shell's 08/14/12 submittal, Figure 1 on page 12 depicts the instability of the E-POD control system when trying to attain too high a NOx control efficiency. What NOx control efficiency set point was the engine set at when these data were collected?

Figure 1 of the November revision application provides data taken while testing the test D399 engine at NC Machinery in Tukwila on April 9, 2012. The tests were performed to determine if the ceramic rope that had been installed in EPOD 1345 would appreciably reduce ammonia slip. During the course of the test, Shell noticed wide swings in the NOx emissions. The Avogadro Group FTIR operator captured the data and prepared this plot. The NOx reduction target during the tests was set at 97%.

9. Please confirm that the CDPF units installed on Discoverer emission units FD-1 through FD-6 and FD-9 are the "CARB verified PERMIT" units described in the Clean AIR Systems document included as Appendix E to the application. The Clean AIR document refers to "non-verified" units, and it is not clear that the same emission reduction guarantees apply to the non-verified units.

On January 8, 2013, Mr. Zach Hedgpeth with EPA Region 10 spoke with Mr. Jim Peltier of Caterpillar Emissions Solutions by phone. Mr. Peltier indicated to Mr. Hedgpeth that "CARB verified PERMIT" units are those units that are installed on engines model year 1996 or newer and have undergone specific testing to meet certain emission standards applicable in California. CDPFs installed as "CARB verified PERMIT" units and "non-verified" units are constructed similarly and operate in the same manner.

10. Zach Hedgpeth requested a log of when the Noble Discoverer E-PODs were serviced for cleanings.

The following table presents that information as extracted from a Noble Corporation maintenance log.

Discoverer EPOD Service Cleaning   Noble Permit-To-Work
09-24-12   Cleaned No. 4 (FD-4) P-T-O # C 308057
09-25-12   Cleaned No. 3 (FD-3) P-T-O # C NCP Log
09-26-12   Cleaned No. 6 (FD-6) P-T-O # C 302284
09-27-12   Cleaned No. 2 (FD-2) P-T-O # C 308021
09-28-12   Cleaned No. 5 (FD-5) P-T-O # C 308028
09-29-12   Cleaned No. 1 (FD-1) P-T-O # C 308081

09-30-12   Cleaned No. 4 (FD-4) P-T-O # C 308086
10-04-12   Cleaned No. 3 (FD-3) P-T-O # C 308035

10-05-12   Cleaned No. 4 (FD-4) P-T-O # C 308096
10-06-12   Cleaned No. 5 (FD-5) P-T-O # C 308037
10-14-12   Cleaned No. 6 (FD-6) P-T-O # C 308105
10-15-12   Cleaned No. 5 (FD-5) P-T-O # C 308110
10-19-12   Cleaned No. 2 (FD-2) P-T-O # C 302288
10-20-12   Cleaned No. 4 (FD-4) P-T-O # C 302289
10-20-12   Cleaned No. 5 (FD-5) P-T-O # C 302290
10-20-12   Cleaned No. 3 (FD-3) P-T-O # C 308118
10-21-12   Cleaned No. 1 (FD-1) P-T-O # C 302292
10-21-12   Cleaned No. 6 (FD-6) P-T-O # C 302291

BACT References Not Provided

A. Page 11. 06/28/12 email from Brian Huffman which is the primary basis for the recommended E-POD NOx reduction targets.

Please find "A. Re: Discoverer E-POD NOx control targets.pdf" on the enclosed flash drive.

B. Page 73. 11/26/12 email from Garth Pulkkinen, Noble Drilling (U. S.) LLC Operations Manager-Alaska, to Rodger Steen and Jim Miller, subject "Disco crane replacement argument", related to the argument that crane engine replacement is technically infeasible.

Please find "B. Fwd Disco crane replacement argument – to supplement.pdf" on the enclosed flash drive.

C. Page 74. 11/09/12 email from Garth Pulkkinen, Noble Drilling (U. S.) LLC Operations Manager-Alaska, to Rodger Steen, subject "Cost detail for hypothetical crane change out on Discoverer", related to crane replacement costs.

Please find "C. Garth – Crane replacement cost.pdf" on the enclosed flash drive.

D. Page 75. 11/13/12 email from Billy Coskrey Halliburton Technology, to Ronnie Holubec, subject "C9 Tier III Engine", related to technical feasibility of Tier 4 engines on drill ships.

Please find "D. Halliburton Tier 3 logic.pdf" on the enclosed flash drive.

E. Page 91. 04125111 letter from EPA Region 7 regarding engine startup periods.

Please find "E. RICE Startup Determination.pdf" on the enclosed flash drive.

Modeling Request

Either a spreadsheet or a post process file that contains the annual PM 2.5 averages across the two years modeled, by receptor. Shell needs to include this step to document compliance with the PM2,5 national ambient air quality standards. Shell only provided raw model output, with a final average value in the modeling report. It is not straightforward to. go. from the raw output provided to the value in the pdf. The intermediate step to get from the raw outputs to the final average is needed for public review.

PM2.5 and PM10 modeling runs that contain the correct emission rate for the resupply ship while operating in Dynamic Positioning mode.

CO and SO2 modeling that contains the correct emission rates for the various incinerators.

Responses to these three requests were provided previously by email from Kirk Winges to Andy Hawkins of EPA on November 20, 2012 and data files were mailed to EPA on December 20, 2012. The electronic files were also delivered January 4, 2013. Please see "ModelingFileRevisions.pdf" and the accompanying model files supplied on the flash drive

Appendix D. Air Quality Modeling Analysis

D-1. Introduction

EPA issued a Prevention of Significant Deterioration (PSD) Permit to Construct (the Permit) to Shell Gulf of Mexico Inc. (Shell) in September 2011.[1] ENVIRON conducted an air quality modeling analysis to confirm that proposed revisions to the Permit will not cause concentrations of criteria pollutants to exceed ambient air quality standards or Prevention of Significant Deterioration (PSD) increments. The PSD increment analysis performed here addresses Class II increments. There are different PSD increments for Class I areas (National parks, Wilderness Areas, etc.), but there are no Class I areas within proximity to the project area, and no Class I area impact analysis has been included in this air quality analysis.

Ambient air quality standards and PSD increments are unique for each airborne contaminant and also refer to specific averaging times. In some cases a specific air contaminant will have separate ambient standards or PSD increments for different averaging times. Table D-1 shows the ambient standards and PSD increments relevant to this air quality modeling analysis. To determine compliance with ambient air quality standards, the analysis adds predicted concentrations attributable to the project to background concentrations. Compliance with PSD increments is determined in this case solely on concentrations attributable to the project.

Table D-1: Summary of Applicable Standards

Pollutant	Averaging Time	NAAQS[1] ($\mu g/m^3$)	PSD Class II Increment ($\mu g/m^3$)
Nitrogen Dioxide (NO_2)	1-hour	188[2]	Not Established
	Annual	100	25
Particulate Matter (PM_{10})	24-hour	150	30
	Annual[3]	50	17
Particulate Matter ($PM_{2.5}$)	24-hour	35	9
	Annual	15	4
Sulfur Dioxide (SO_2)	1-hour	196[3]	Not established
	3-hour	1,300	512
	24-hour	365	91
	Annual	80	20
Carbon Monoxide (CO)	1-hour	40,000	None
	8-hour	10,000	None

[1] National Ambient Air Quality Standards

[2] Based on 98th percentile of daily maximum hourly-averaged concentrations

[3] Based on 99th percentile of daily maximum hourly-averaged concentrations

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[1] Outer Continental Shelf Prevention of Significant Deterioration Permit to Construct, Permit Number R10OCS/PSD-AK-09-01, Issuance Date September 19, 2011, Issuing Authority, United States Environmental protection Agency, Region 10.

The modeling analysis consists of the following steps:

- Model Selection

- Preparation of model inputs

- Exercising the model to compute ambient air concentration estimates

- Comparing model-predicted concentrations with ambient air quality standards.

Except as discussed below, this air quality modeling analysis uses the same techniques and data as the previous permit modeling analyses conducted in support of the application leading to the Permit. This appendix describes the current analysis in detail, but also relies, in part, on previous documentation. References to the phrases "previous analysis" or "previous modeling analysis" in this appendix refer to the cumulative documentation submitted by Shell as part of the air quality modeling demonstration for the 2011 permit.

D-2. Model Selection

The dispersion model used in the previous and current modeling analyses is EPA's AERMOD model.[2] AERMOD is the primary regulatory model used throughout the United States to evaluate the impact of stationary source emissions. It is recommended by EPA in formal guidance in 40 CFR Part 51, Appendix W, known as the Guideline on Air Quality Models.

The AERMOD modeling system also requires a series of support programs used to prepare information for use in the dispersion model. Key among these programs is the meteorological data pre-processor, known as AERMET. In the previous modeling analysis, AERMET was judged to be appropriate and was used for modeling during conditions when the surface of the Arctic Ocean was covered primarily in ice. This ice covering closely resembles land surface, for which the AERMET pre-processer was developed.

However, during conditions of open water, the AERMET pre-processor was judged inappropriate due to air/sea interface effects that change how air contaminants transport and disperse in the atmosphere over open water, a condition not well represented by the AERMET pre-processor. An alternative technique was adapted and used in the previous application based on the Coupled Ocean-Atmosphere Response Experiment (COARE) algorithm. Accordingly, the modeling system used in the previous application was referred to as the COARE-AERMOD system.

This current modeling analysis also uses AERMOD with the AERMET pre-processor for ice conditions and the COARE algorithm for preparing meteorological data during open-water conditions. The only model-selection difference between the current and previous modeling analyses is the version of the AERMOD model itself. The previous analysis used the older version of AERMOD, designated as version 09292, while the current analysis uses the more-recent 12060 version. The two versions appear to give identical concentration calculations. The only difference between these two model versions is that when using the model to compute

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[2] http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod

concentrations of Nitrogen Dioxide (NO_2), the newer version requires one full year of meteorological data. Because the Shell exploration fleet will only be present in the Chukchi Sea for 120 days in any given drilling season, the previous modeling analysis only supplied meteorological data for the period being actually modeled. The additional hours of meteorological data must be provided to the current version of the model, but these meteorological data do not enter into the concentration calculations because the Shell emissions units have no emissions during these time periods. Accordingly, arbitrary or "dummy" data were provided to the model for the periods when Shell emissions units were not present. Other than this inconsequential difference, the meteorological data used in the current modeling analysis were identical to those used previously.

D-3. Preparation of Input Data

Model input data fall into three categories:

1. Emission unit information

2. Meteorological data

3. Receptor data

As discussed above, meteorological data are identical to those used in the previous modeling analysis. A complete discussion of these data is provided in Shell's March 18, 2011 submission to EPA.[3] The receptors used in the air quality modeling analysis are also identical to those used in the previous air quality modeling analysis. These are also discussed in the March 18, 2011 submission, and also in the EPA's Technical Support Document.[4]

The only difference in the current modeling analyses from the previous modeling analyses is in the emission unit information. Emission unit information can be further divided into two categories: emission unit configuration and emission rates.

D-3.1 Emission Unit Configuration

The emission unit configuration category includes the locations, heights, areas and other emission unit parameters. None of these configuration factors were changed from the previous modeling analysis. Some of the emission units are classified as POINT sources in the AERMOD terminology, and for those sources, the same locations, release heights, exhaust temperatures, exhaust velocities and stack diameters were used in the current modeling as were used in the previous modeling analysis. These are detailed in the Figure 3 and Table 5 of the Technical Support Document.[5]

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[3] Discoverer Drillship Impact Evaluation for SO_2 and NO_2 Using AERMOD, Chukchi and Beaufort Seas, Shell Alaska Exploratory Drilling Program, Prepared by Air Sciences, Inc., Golden, CO, Project 180-20-3, March 18, 2011.
[4]

ftp://ftp.epa.gov/reg10ftp/alaska/ocs/chukchi/air/shell/discoverer/2011/discoverer_ambient_air_quality_impact_analysis_06242011.pdf pages 9-11

[5] Ibid pages 11-16

The remaining sources were classified in the AERMOD terminology as AREAPOLY sources, meaning they are area sources with an irregular shape defined by a series of vertices that represent a polygon. The emission source configuration for these sources was also identical to the previous air quality modeling analysis. Figure 1 shows the general arrangement of these AREAPOLY sources as used both in the previous modeling analysis and the current modeling
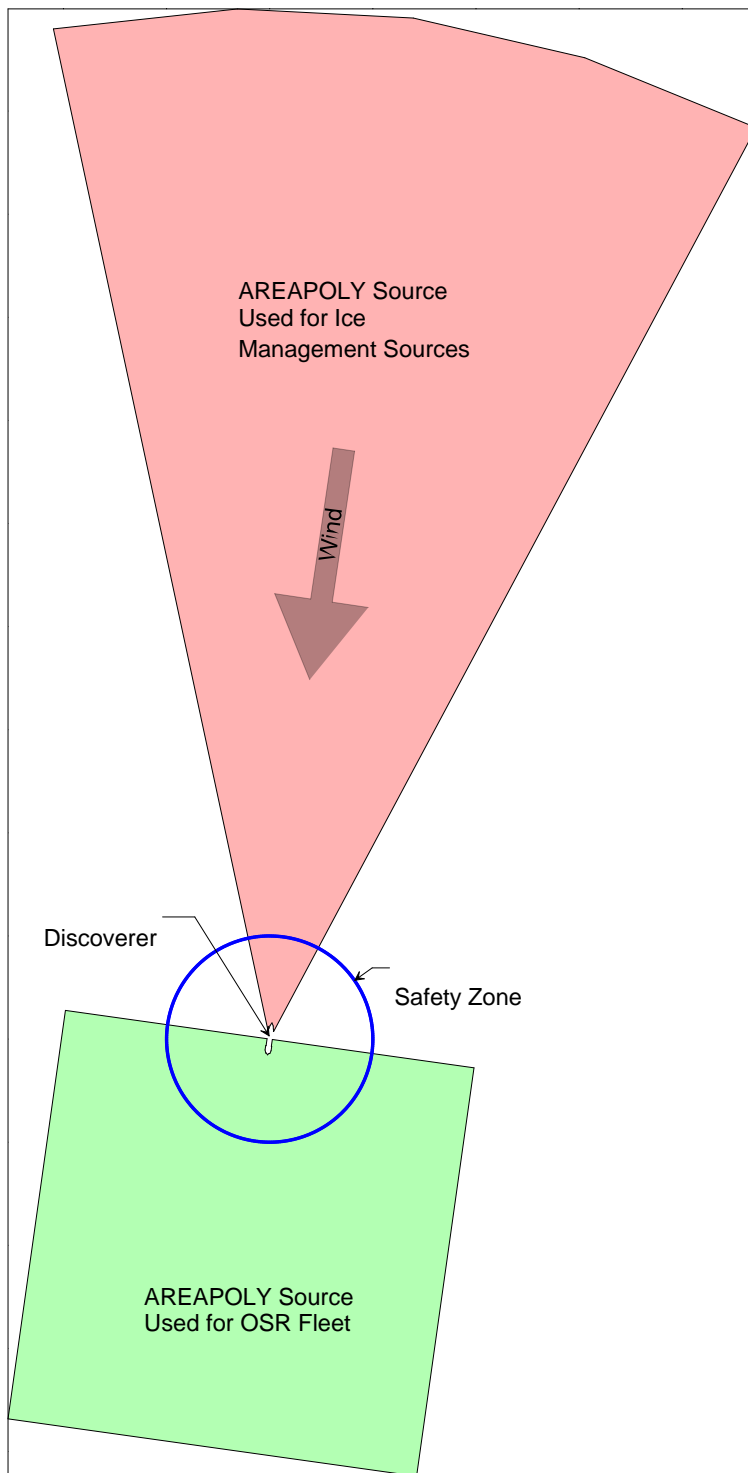
AREAPOLY Source
Used for Ice
Management Sources

Wind

Discoverer

Safety Zone

AREAPOLY Source
Used for OSR Fleet

Figure D-1. AREAPOLY Source Configuration

analysis. It should be noted that the sources will rotate about the drill hole location with the wind direction so that for each hour, a different orientation will be observed aligning with the wind direction. Figure D-1 presents the configuration for a wind direction of 8 degrees east of north (direction from which the wind is coming).

Both the previous and current modeling analyses used emission sequences due to the fact that the emissions units for the exploration program do not run continuously, and in some cases are mutually exclusive. For example, one of the early exploration steps is developing a mud-line cellar. Some of the emissions units used in mud-line cellar development are unique to this task and not used in other phases of the drilling program. Conversely, a later phase of the exploration program involves a process called logging and cementing. Like mud-line cellar development, cementing and logging involves specialized emission units. These drilling program phases cannot occur simultaneously, and the specialized emission units used in these phases cannot operate simultaneously. And other emission units, such as the supply ship during the deliveries, the solid waste incinerator, the testing of the emergency generator and the main ice breaker that all operate intermittently.

To address this, emission sequences were developed reflecting the different drilling program phases. A schedule of emissions was developed for a full 120-day drilling season where each emissions unit was assigned operating hours based on expected activity. For some emissions units, such as the main generator engines, the heaters, the cranes, the anchor handler and the oil-spill recovery fleet, emissions were assumed to occur continuously for the entire 120-day drilling season, although this assumption is highly conservative because these emissions units operate intermittently. The conservative assumption was made because these emissions units have no definable pattern of operation.

For other emissions units, such as the mud-line cellar compressor engines, the high pressure units, the ice breaker, the incinerator, the emergency generator, and the supply ship, a pattern or sequence of emission was established. Table D-2 describes the emission sequence for each emissions unit.

Table D-2. Emission Sequences		
Emission Unit	**Hours Per Season**	**Description**
Main generators	2,880	Operate continuously
Emergency Generator	8	Operate for 2 hours, once per month
Mud-Line Cellar Compressors	480	Operate for 5 days to make one MLC for each drill hole and assume 4 drill holes per season
High Pressure Unit Engines	480	Operate for 5 days to make one MLC for each drill hole and assume 4 drill holes per season
Port Crane Engine	2,880	Operate continuously
Starboard Crane Engine	2,880	Operate continuously
Cementing/Logging Engines	1,248	Operate for 13 days to log/cement each drill hole and assume 4 drill holes per season
Heaters	2,880	Operate continuously
Seldom-Used Engines	2,880	Operate continuously
Incinerator	600	Operate 5 hours per day every day
Resupply Ship	624	Operate for 24 hours in DP mode and 2 hours in transit mode for each of 24 visits to the drill site
Ice Breaker	1,224	Operate during periods of ice only
Anchor Handler	2,880	Operate continuously
Oil-Spill Response Main Ships	2,880	Operate continuously
Oil-Spill Response Work Boats	2,880	Operate continuously

The same emission sequences used in the previous modeling analysis were used in the current analysis, with the following exception:

- The incinerator was further restricted from operating on days when the resupply ship was operating in dynamic positioning (DP) mode. With this restriction, the number of hours of operation for the incinerator was reduced from 600 to 480.

One other difference between the current and previous modeling analyses was the way in which the model runs were made. Previously, individual hours were modeled in separate runs of AERMOD. For each drill sequence, there were 2,880 separate runs of the AERMOD model. This approach was not possible in the current modeling analysis because the newer version of AERMOD requires a full year of meteorological data when modeling NOx. An alternative, but mathematically identical approach was used in the current modeling analysis. Runs for each sequence were made in a single full-year model run of AERMOD (with dummy meteorological data for the non-drill season hours, as noted above). The approach was to define 360 different model sources for each emission unit, one for each of the 360 degrees of wind direction. So instead of 16 model sources used previously, the current modeling analysis used 16 x 360 = 5,760 model sources.[6] A large hourly emission file was created that then inserted an emission rate of zero for 359 of the 360 sources for each hour and only inserted the actual emission rate for the emission source that reflected the wind direction in that hour.

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[6] There are 15 sources listed in Table D-2, but the Resupply ship is modeled as a separate source when in DP mode versus transit mode.

For example, the main generators were represented by 360 different model sources with names MAIN0, MAIN1, MAIN2…MAIN359. In the first drill season hour of the 2009 meteorological data, the wind direction is 8, meaning that the wind during that hour is coming 8 degrees measured clockwise from north, or slightly east of north as shown in Figure D-1. For this hour, all of the MAIN emission sources are set to an emission rate of zero, except MAIN8 which has the actual emission rate for the generators during that hour. As a test, this model approach was run with the emission data from the previous modeling analysis and identical results were obtained.

Another consideration addressed in the previous modeling analysis was the start date of the drill season. The drill season is limited by the terms of the permit to 120 days, but those 120 days must occur within a 153-day window between July 1 and November 30. To take advantage of the full 120-day drilling season, Shell must commence the program between July 1 and August 3. Consequently, two start sequences were evaluated: one starting on July 1, called the "A sequence" and one starting on August 3, called the "B sequence." The current modeling used the same two sequences.

D-3.2 Emission Rates

This permit application requests revisions in the allowable emission rates of some emissions units. A summary of the requested emission rate changes follows:

For NOx:

- The application asks to raise the NOx emission factor for the main generators from 0.5 grams per kilowatt-hour (g/kW-hr) to 6.0 g/kW-hr. This affects both the hourly and annual emissions of NOx for the main generators. The Permit limits aggregate NOx emissions to 4.64 lb/hr, but this application requests the hourly NOx emission limit to be increased to 55.72 lb/hr. The Permit limits aggregate annual emissions to 5.83 tons per rolling 12-month average. This application requests that this limit be increased to 44.83 tons per rolling 12-month average (a 39-ton increase).

- The application asks to change the hourly NOx emissions from the deck cranes. The current limit is based on cranes operating at 40% load capacity and no more than 50% functioning time, for a net restriction on an hourly basis of only 20% of the potential emissions. The application seeks to remove the hourly restriction on crane use, which will change the current aggregate NOx emission limit from 2.48 lb/hr to 12.40 lb/hr.

- For the cementing and logging engines the Permit allows five separate engines to operate at an emission factor of 15.717 g/kW-hr. Three of these engines have now been converted to electric motors powered by the main generators, so there are only two remaining diesel-fueled cementing unit engines.

  The Permit limits aggregate daily fuel use to 320 gallons. Shell proposes keep this daily fuel limit. Although the Permit does not limit hourly fuel consumption directly, there is an effective hourly limit on fuel consumption to one twenty-fourth of the daily limit because hourly NOx emission are limited to 6.56 lb/hr, which is one twenty-fourth of the daily NOx emissions that would result from the daily fuel limit of 320 gallons. This application

proposes to revise the hourly emission limit from the present 6.56 lb/hr to 11.60 lb/hr. The effect of this request is that while Shell will continue to be limited to no more than 320 gallons per day of fuel for the cementing and logging engines, during any one hour they may burn as much as 28.2 gallons of fuel.

For PM

- For the deck crane engines, the Permit limits PM, PM_{10} and $PM_{2.5}$ to 0.0715 g/kW-hr. The application requests approval to operate these units without CDPFs and to revise the BACT limit to 0.4767 g/kW-hr, and requests that the daily allowable PM, PM_{10} and $PM_{2.5}$ emission rates be increased to 2.75 lb.

- As noted above, the Permit authorizes five cementing and logging engines and uses a single emission factor to calculate emissions from all engines. Three of these engines have been converted to electric power supplied by the main generators, so only two engines are emission units. The BACT limit for PM, PM_{10} and $PM_{2.5}$ in the Permit for the two remaining engines is 0.253 g/kW-hr, but the higher emission factor of 0.386 g/kW-hr (for an electrified engine) was the basis for the maximum daily PM emissions from the combined 5 engines. The application requests that the requirement to employ CDPFs be rescinded, that the BACT limit be revised to 1.69 g/kW-hr for PM, PM_{10}, and $PM_{2.5}$, and that the allowable daily PM, PM_{10}, and $PM_{2.5}$ emissions be revised to 16.88 lb/day.

- The Permit limits the resupply ship PM, PM_{10} and $PM_{2.5}$ emissions to 75.09 lb/day during periods when it is operating in dynamic positioning mode near the Discoverer. The application requests a revision in resupply ship PM, PM_{10} and $PM_{2.5}$ emissions to 48.80 lb/day.

- The Permit limits PM_{10} and $PM_{2.5}$ emissions from the Oil-Spill Response Main Ship (Nanuq) to 3.03 lb/day. The application requests a revised allowable PM, PM_{10}, and $PM_{2.5}$ limit of 10 lb/day.

For CO

- The application requests an increase in the emission factor for CO for the deck crane engines from the present permit limit of 0.220 g/kW-hr to 2.2 g/kW-hr. There is also an increase in the utilization requested for the 1-hour period, as described under NOx above. The net effect is an increase in the CO emission rate from the current level of 0.11 lb/hr to 2.64 lb/hr.

- The application requests an increase in the emission factor for CO from the cementing engines from the present permit limit of 0.4 g/kW-hr to 4.0 g/kW-hr. The net effect is an increase in the CO emission rate from the current level of 0.37 lb/hr to 3.53 lb/hr.

For SO_2

- The increased utilization of the deck cranes as described under NOx above results in an increase in SO2 emissions on a peak-hour basis from the current permit limit of 0.00326 lb/hr to 0.00814 lb/hr.

Table D-3 summarizes the emission changes requested as part of this application for NO_x and PM.

Table D-3. Summary of Requested Emission Changes in Permit Limits for NOx and PM										
Emission Source	NOx						PM, PM$_{10}$ and PM$_{2.5}$			
	Emission Factor (g/kW-hr)		Maximum Hourly Emissions (lb/hr)		Maximum Annual Emissions (t/y)		Emission Factor (g/kW-hr)		Maximum Daily Emissions (lb/day)	
	Current Permit	Proposed	Current Permit	Proposed	Current Permit	Proposed	Current Permit	Proposed	Current Permit	Proposed
Main Generators	0.5	6.0	4.64	55.72	5.83	44.83	0.127	0.127	28.3	28.3
Emergency Generator	none	None	19.73	19.73	-[1]	-[1]	none	none	2.77	2.77
MLC Compressor Engines	4.0	4.0	7.11	7.11	1.71	1.71	0.1	0.1	4.26	4.26
HPU Engines	4.0	4.0	3.29	3.29	0.79	0.79	0.03	0.03	0.59	0.59
Deck Cranes	10.327	10.327	2.48	12.40	2.76	2.76	0.0715	0.4767	0.41	2.75
Cementing and Logging Engines	13.155	13.155	6.56	11.60	4.09	4.09	0.253	1.69	3.87	16.88
Heat Boilers	0.20[2]	0.20[2]	3.19	3.19	4.59	4.59	0.235[2]	0.235[2]	8.99	8.99
Seldom-Used Engines	none	None	none	None	none	none	none	none	none	none
Incinerator	5.0[3]	5.0[3]	0.65	0.65	0.20	0.20	8.2[3] 7.0[4]	8.2[3] 7.0[4]	5.33[3] 4.55[4]	5.33[3] 4.55[4]
Resupply- DP	none	None	117.39	117.39	none	none	none	none	75.09	48.80
Resupply – Transit	none	None	none	None	none	none	none	none	none	None
Ice Breaker	none	None	67.96	67.96	41.59	41.59	none	none	277.47 269.66[5]	277.47 269.66[5]
Anchor Handler	none	None	69.06	69.06	99.45	99.45	none	none	281.46 273.82[5]	281.46 273.82[5]
OSR Main Ship Engines	none	None	67.44	67.44	97.11	97.11	none	none	3.03	10.0
OSR Main Other Srcs	none	None	none	None	none	none	none	none	none	None
OSR Work Boats	none	None	13.24	13.24	19.07	19.07	none	none	24.34	24.34

[1] annual and daily emissions for the emergency generator are effectively limited by operational limits of 10 hr/yr and 2 hr/day.

[2] emission factors for the heat boilers are in lb/MMBtu

[3] emission factors for the incinerator are in lb/ton of waste incinerated

[4] separate emission factors and emissions for PM$_{10}$ (8.2 lb/ton and 5.33 lb/day) and PM$_{2.5}$ (7.0 lb/ton and 4.55 lb/day)

[5] Separate emission limits are provided for PM$_{10}$ (top) and PM$_{2.5}$ (bottom)

Table D-4 shows the emission rates used in the current modeling analysis. These emission rates differ, in some cases, from those shown in Table D-3 for several reasons. First, while Table D-3 refers to explicit emission limits in the Permit, a number of emissions units are not subject to explicit numerical limits, but rather to operational limits, such as fuel limits, which effectively limit emissions. Second, the modeling also includes emissions from engines even if those emissions are not explicitly or operationally limited by the Permit. Finally, there are some cases where a higher emission rate was used in the air quality modeling than the Permit limit. The use of higher emission rates in the modeling ensures conservatism (over-prediction) in the modeling analysis and was generally done to account for short-term conditions, such as start-up (see discussion below). The purpose of using higher emission rates in the modeling is to provide added assurance that the ambient air quality standards and/or PSD increments will not be exceeded as a result of a short-term emission condition.

Table D-4. Modeled Emission Rates						
Emissions Unit	NOx		PM$_{2.5}$	PM$_{10}$	CO	SO$_2$
	lb/hr	t/y	lb/day[1]	lb/day[1]	lb/hr	lb/hr[2]
Main Generators	63.11	44.83	28.31	28.31	1.66	0.06
Emergency Generator	19.73	0.08	2.77	2.77	4.25	0.01
MLC Compressor Engines	7.11	1.71	4.26	4.26	3.30	0.01
HPU Engines	3.29	0.79	0.59	0.59	0.58	0.01
Deck Cranes	12.40	2.76	2.75	2.75	2.64	0.01
Cementing and Logging Engines	11.60	4.09	16.88	16.88	3.53	0.01
Heat Boilers	3.19	4.59	8.99	8.99	1.23	0.03
Seldom-Used Engines	0.52	0.75	0.88	0.88	0.11	0.00
Incinerator	0.83	0.20	4.55	5.33	4.28	0.35
Resupply- DP	117.39	33.81	48.80	48.80	79.80[3]	0.13[3]
Resupply – Transit	35.01	0.82	1.87	1.87	7.54	0.013
Ice Breaker	191.29[4]	41.59	269.75	277.51	53.25	0.487
Anchor Handler	196.21[4]	99.45	273.76	281.52	53.94	0.486
OSR Main Ship	68.10	98.07	24.24	30.54	19.19	0.190
OSR Work Boats	13.24	19.07	24.34	24.34	2.18	0.004

[1]Daily emission rates were used for modeling all averaging times for PM$_{2.5}$ and PM$_{10}$.

[2]Hourly emission rates were used for modeling all averaging times for SO2.

[3]At any given time the resupply ship is either in transit or in DP, so only one of the two modes occurs at any one time

[4]Emissions shown in the table are for peak hours during start-up. In non-start-up hours, hourly NOx emissions are 67.94 lb/hr for the ice breaker and 69.06 lb/hr for the anchor handler.

D-3.3 Start-Up Emissions

Except as noted in Table D-2, the modeling analysis assumes engines are operating all the time. In practice, engines are turned off when they are not needed, which eliminates emissions from those engines. As a result, the modeling assumptions can generally be assumed to be

conservative (over-predicting) because they assume that engines are operating when in fact there are times when they are not. This is especially true for longer time periods such as a full day or the entire drilling season.

As discussed in Chapter 6 of the application, an engine starting up emits at a higher rate if there is an emission control device attached because most of the control devices do not function well until warmed to operating temperature. While over a 24-hour period or the entire drilling season, these short-term emission increases would be more than compensated for by the downtime of the engine shut-down, for an hour it is likely that emissions could be higher. These higher emissions during start-up are a normal, unavoidable occurrence with every engine equipped with emission controls.

In order to ensure that start-up emissions do not cause concentrations that exceed short-term standards, the current modeling assumes that NOx emissions from SCR-controlled engines would be higher for an hour for each startup. These include the Discoverer's main generators and certain larger engines on the two ice management vessels. The following assumptions were made to calculate start-up emissions:

- Emissions for an engine during start-up are equivalent to uncontrolled engine emissions at full load.

- Start-up emissions last for 1-hour

- For the main generators, it was assumed that two of the six engines could be in start-up mode at any time. It is recognized that this greatly over-states the number of start-up events.

- For the ice breaker and the anchor handler, one quarter of the total engine horsepower on each vessel was assumed to start-up 6 times per day. Essentially, every fourth hour was assumed to be a "start-up hour" in which one quarter of the engine capacity was assumed to be uncontrolled.

D-4. Model Results

D-4.1 Criteria Pollutant Analysis

AERMOD was used to establish pollutant concentrations at each of the 2,082 receptors for each hour of the meteorological data set. These hourly results were then sorted and averaged to determine the compliance with the ambient criteria shown in Table D-1. For compliance with the NAAQS, a background concentration, which includes the effects of natural background and man-made sources of emission not included in the air quality modeling, must be added to the model results. The background values used here are the same as was used in the previous air quality modeling analysis.[7] Comparison with PSD increments does not require the addition of a background concentration. Table D-5 summarizes the model results.

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[7]

ftp://ftp.epa.gov/reg10ftp/alaska/ocs/chukchi/air/shell/discoverer/2011/discoverer_ambient_air_quality_impact_analysis_06242011.pdf page 31

Table D-5. Summary of Model Results

Air Pollutant	Averaging Period	Shell Only Impacts (without background) ($\mu g/m^3$)	PSD Increment ($\mu g/m^3$)	Exceeds PSD Increment?	Background Concentration ($\mu g/m^3$)	Total Impact Including Background ($\mu g/m^3$)	NNAQS or AAQS ($\mu g/m^3$)	Exceeds NAAQS?
NO$_2$	1-hour	150.4	None	No	13.2	163.6	188	No
	Annual	10.2	25	No	2.0	12.2	100	No
PM$_{2.5}$	24-hour	8.9[1]	9	No	11.0	20.6[1]	35	No
	Annual	1.7	4	No	2.0	3.7	15	No
PM$_{10}$	24-hour	9.0	30	No	79.0	89.1	150	No
SO$_2$	1-hour	16.2	None	No	23.0	39.2	196	No
	3-hour	11.0	512	No	14.0	25.0	1300	No
	24-hour	1.7	91	No	5.0	6.7	365	No
	Annual	0.1	20	No	0.4	0.5	80	No
CO	1-hour	1,084	None	No	959.0	2,043	40000	No
	8-hour	593	None	No	945.0	1,538	10000	No

[1]The metric used for PM$_{2.5}$ is different for the PSD increment and the NAAQS. For the PSD increment, the highest second high at each receptor is determined for each of the 4 model sequences for PM$_{2.5}$ (2009A, 2009B, 2010A, 2010B) and the highest of these four values is shown in the table at 8.9 $\mu g/m^3$. For the NAAQS, the highest value at each receptor for the two 2009 sequences is averaged with the highest value for the two 2010 sequences. The highest of these values across all receptors was 9.6 $\mu g/m^3$, which when added to the background concentration of 11.0 is 20.6 $\mu g/m^3$ as shown in the table.

The modeling results summarized in Table D-5 demonstrate that emissions attributable to the Discoverer and its associated fleet, as revised in this permit application, continue to comply with ambient air quality standards and PSD increments.

D-4.2 Secondary Aerosols

Secondary aerosols are small particles that form in the air as a result of the interaction of certain gases. In particular, nitrogen dioxide and sulfur dioxide can combine with ammonia to form ammonium nitrate and ammonium sulfate, common secondary aerosols. Because the Shell exploration program produces emissions of these gases, EPA has previously asked Shell to evaluate the potential impact of any secondary aerosols in the villages that border the Chukchi Sea. Note that it takes time for the secondary aerosol chemistry to occur, and modeling analyses virtually always show higher PM concentrations near a source due to directly emitted particulate matter. However, over long distances, secondary aerosol formation can have a more significant contribution to total PM concentrations.

To evaluate secondary aerosols, receptors were placed at both Point Lay and Wainwright, as well as at over-water locations at a distance of 50 kilometers on a direct line with each village. Intermediate receptors were included because AERMOD is only recommended for calculating concentrations up to 50 kilometers, and both villages are farther than 50 kilometers from the drilling locations in the Chukchi Sea.

Table D-6 shows the concentrations of NO_2 and SO_2 calculated at these locations. In the Table, 24-hour average concentrations are used although there are no formal criteria for nitrate or sulfate. For purposes of this conservative analysis, we have assumed 100% of the NO_2 would convert to nitrate and 100% of the SO_2 would convert to sulfate. It is unlikely that this rate of conversion would be obtained, so the concentrations in Table D-6 should be considered an over-estimate of possible nitrate or sulfate concentrations.

Table D-6. Chukchi Sea Village Concentrations in µg/m³				
Location	NO2 Concentration	SO2 Concentration	Nitrate Concentration If 100% Converts	Sulfate Concentration If 100% Converts
Point Lay Village	2.3	<0.1	4.0	<0.1
Wainwright Village	2.8	<0.1	4.9	<0.1
Receptor in the Direction of Point Lay at a Distance of 50 km from the Discoverer	4.6	<0.1	8.1	<0.1
Receptor in the Direction of Wainwright at a Distance of 50 km from the Discoverer	5.1	<0.1	8.8	<0.1

There are no ambient criteria specific to sulfate or nitrate, but these particulate concentrations are well below the 35 µg/m³ ambient air quality standard for PM2.5.

December 20, 2012

Andy,

As I prepared the electronic modeling files to send for your review of Shell's November 29, 2012 PSD permit revision application, I discovered a number of minor inconsistencies between the application text and the modeling files. After correcting these inconsistencies, I reran the modeling to bring everything up to date. There are no substantive changes in the modeling results. The revised modeling appendix (Appendix D of the November 29 permit application) is attached in "marked text" and "changes accepted" formats. Following is a brief explanation of the changes I made that are reflected in the revised modeling appendix.

1. Page D-9 of the text and Table D-3 of the November 29 application request a revision in the daily PM2.5 emission limit from the current 75.09 lb/day to 52.55 lb/day. The modeling was conducted assuming 48.80 lb/day, but the text and Table D-3 were not changed to match the modeling.   I revised the text to reflect the correct emission limit (48.8 lb/day). This change will also need to be made to Section 7.3.1 of the application, which we will do when we formally submit a revised application and appendix after receiving further input from EPA.

2. I adjusted the way I calculated supply ship fuel consumption by increasing the fuel used during the time the ship is sufficiently close to the Discoverer to include its emissions in the modeling.

3. Table D-4 of the November 29 application showed total emissions of CO and SO2 for the resupply ship while in transit mode, rather than just showing the portion which was modeled. While not an error, it is more correct and more consistent with the other pollutants to show the CO and SO2 emissions using the same calculation method as was done for NOx. I decreased the CO and SO2 emissions in Table D-4 to reflect this.

4. CO and SO2 emissions from the incinerators on the ice breaker, the anchor handler and the OSR Main ship were not included in the modeling submitted with the November 29 application. They were added in for this latest revision.

5. Modeling of annual-average NOx concentrations in the November 29 application was performed by scaling the short-term model runs using the ratio of long-term to short-term emission rates. Because the NOx modeling used the PVMRM algorithm, which is non-linear with emission rate, for the revised modeling it was more appropriate to calculate annual-average concentrations using separate runs with annual-average emission rates.

6. The November 29 application reported modeling results in Table D-5. The modeling results for 1-hour NOx were based on the emission rates shown in Table D-4 except that emissions from cementing engines in the model runs were 13.86 lb/hr, not the 11.60 lb/hr shown in the Table. To be consistent with the permit application request, the revised model results have been based on an hourly NOx emission rate of 11.6 pounds for the cementing engines.

7. One element of the modeling provided in the November 29 application warrants further explanation. The modeling provides a conservative assessment of annual impacts because it models an hourly emission rate that is higher than the permitted hourly emission rate. The modeling takes this approach because the November 29 application requests a prohibition on using the Discoverer incinerator when

the resupply ship operates in DP mode adjacent to the Discoverer. To be conservative, the 2011 air quality modeling assumed 600 hours of incinerator operation per drilling season (5 hours of operation/day for 120 days). Incorporating the requested restriction preventing incinerator operation during resupply visits, the number of hours of incinerator operation assumed in the modeling drops from 600 to 480 per drilling season if 24 supply trips are assumed. This is because while the restriction has no effect on maximum hourly or maximum daily emission rates, with fewer hours of incinerator operation, the restriction could reduce annual emissions if the supply ship were to come as often as modeled. Shell is not asking to revise the current incinerator annual limit because if the supply ship makes fewer visits, potential annual incinerator emissions could approach the current permit limit. So, to accommodate the current annual emission limit in the air quality modeling, the hourly emission rate was increased for each of the 480 hours in the model runs so that the total would match the current permit annual emission limit.

In addition to the changes detailed above, you will note the modeling files include a combined and much more comprehensive emission spreadsheet that provides a complete link between the emission calculations and assumptions and the actual model-input values used in each run. Additionally, I have prepared a model-results summary spreadsheet that tracks to the model results table in the report.

I hope all of this information facilitates your review and provides clarity when these modeling files are viewed in the future.

Kirk

From: Keith.M.Craik@shell.com
Sent: Tuesday, November 27, 2012 6:05 PM
To: rgsteen@airsci.com; Lindsey, Christopher SEPCO-UAX/A/SD; ehansen@environcorp.com
Subject: FW: Cost Breakdown

Rodger,
Here is the cost estimate furnished by Halliburton.

Keith Craik
Drilling Consultant
Shell International Exploration and Production Inc.
200 North Dairy Ashford, Houston, Texas 77079-1197, USA

Tel: +1 832-337 1792
Email:
Internet: http://www.shell.com/eandp-en

From: Ronnie Holubec [mailto:Ronnie.Holubec@Halliburton.com]
Sent: Tuesday, November 27, 2012 7:50 PM
To: Craik, Keith M SEPCO-UAO/W/A
Cc: Gaylon Deville; Chance Delatte
Subject: Cost Breakdown

Evening Keith.

Please see below for cost breakdown.

Engine Package (Motor,HT-750 & Radiator) - $150K X 2 = $300,000

Modifications for engine package to accept CAT engines - $35,000

Removal of 8V71 package - $36,500

Installation of CAT engine package - $61,500

Transportation - $14,000

Personnel Transportation - $10,000

Total - $457,000

Regards,

Ronnie Holubec
Sr Account Leader
Office 281.988.2112
Cell 281.687.8049

From: Brian R. Huffman [Huffman_Brian_R@cat.com]
Sent: Thursday, June 28, 2012 9:39 AM
To: Eric Hansen
Cc: Miller, Brian H SIEP-PTP/AX
Subject: Re: Discoverer E-POD NOx control targets

Eric,

Response below in red.

Thanks,

Brian Huffman
Industry Segment Manager - Oil & Gas
Caterpillar Emissions Solutions
Office: 713 329 2214
Cell: 309-854-3695
huffman_brian_r@cat.com
http://www.cat.com/engines/emissions-solutions
http://www.cleanairsys.com/

13105 NW Freeway
Houston, TX 77040

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From: Eric Hansen <ehansen@environcorp.com>
To: "Brian Huffman (huffman_brian_r@cat.com)" <Huffman_Brian_R@cat.com>
Cc: Brian Miller <brian.miller@shell.com>
Date: 06/28/2012 12:23 PM
Subject: Discoverer E-POD NOx control targets

Brian,

We understand there is a range of NOx targets one can select with the E-PODs designed for the Discoverer. Can you please address the range of NOx reduction targets that is appropriate for our application?

The E-PODs are designed to maximize performance within the customer defined available space. The acceptable NOx reduction operating range of the systems is 75%-93% for the long units and 75% to 88% for the short units. Engineering analysis shows that 90% and 86% NOx reductions are the ideal reduction levels for the long units and short units, respectively. Pushing the units to 93% and 88% NOx reductions levels can be done to achieve additional NOx reduction at the expense of additional ammonia slip and decrease in system control stability. It is not recommended to operate the systems at reduction levels above 93%. Cat CleanAIR's recommendation is to operate the systems at 90% and 86%, respectively, for the best long term performance and system stability. However, operating the systems at the higher reduction levels is acceptable as long as the ramifications of doing so are acceptable to the operator.

ENVIRON

Eric Hansen | Principal
ENVIRON International Corporation
19020 33rd Avenue West | Suite 310 | Lynnwood, WA 98036
T: +1 425 412 1811 | M: +1 206 794 6012 | F: +1 425 412 1840
ehansen@environcorp.com

From:	Rodger G Steen [rgsteen@airsci.com]
Sent:	Monday, November 26, 2012 11:16 AM
To:	Eric Hansen
Cc:	Craik, Keith M SEPCO-UAO/W/A; Lindsey, Christopher SEPCO-UAX/A/SD
Subject:	Fwd: Disco crane replacement argument - to supplement

Eric,

This should do it for the logic on why Noble cannot just replace the engine on the crane. Do you want to insert it in place of the my earlier logic - for the cranes.

Rodger

Begin forwarded message:

From: "Garth Pulkkinen" <gpulkkinen@noblecorp.com>
Date: November 26, 2012 1:06:11 PM MST
To: "Jim Miller" <Jim.Miller@shell.com>, <rgsteen@airsci.com>
Cc: <ndisuper1@noblecorp.com>, <MBazan@noblecorp.com>
Subject: FW: Disco crane replacement argument - to supplement

Rodger,

On the subject of feasibility of changing engines on the existing National OS435 pedestal cranes, the following could be used to describe it:

When considering possibilities for *Noble Discoverer* cranes moving forward, the option of simply replacing the engine (prime mover) of the existing National OS435 pedestal cranes poses significant technical challenges that render it not feasible. A diesel-hydraulic crane is a complex machine that has multiple functions that depend on precise matching between the prime mover and the hydraulic pumps that power those functions. The prime mover feeds rotating input into a gear set that, in turn, rotates hydraulic pumps. These pumps feed hydraulic pressure and flow to the hydraulic motors that perform the physical work of the crane. The gear set is designed specifically to an engine, and the hydraulics are designed specifically to a gear set, so the entire function of the crane is designed around a specific prime mover, in this case, a specific diesel engine model. The engine and hydraulic crane controls are all designed to enable the crane to perform the following functions in concert:

Slew (rotate) left and right;
Boom raise and lower;
Main hoist raise and lower;
Auxiliary hoist raise and lower

All of these functions are custom to a specific crane and crane power design, as are all the safety devices and controls associated with them. Changing the prime mover of a crane would require the redesign and replacement of all associated functional equipment and controls, which comprise the majority of what a crane physically is, thereby making this not feasible.

Garth Pulkkinen
Operations Manager - Alaska
Noble Drilling (U.S.) LLC
188 W. Northern Lights Blvd.
Suite 620
Anchorage, AK 99503
TEL: +1-907-433-7417
MOB: +1-832-235-4332
FAX: +1-281-596-4462
E-mail: gpulkkinen@noblecorp.com

From: "Garth Pulkkinen" <gpulkkinen@noblecorp.com>
Date: November 9, 2012 12:59:23 PM MST
To: "Rodger Steen" <rgsteen@airsci.com>
Cc: "Christopher Lindsey" <Christopher.Lindsey@shell.com>, "Jim Miller"
<Jim.Miller@SHELL.com>, "Keith Craik" <Keith.M.Craik@shell.com>
Subject: RE: Cost detail for hypothetical crane changeout on Discoverer

Rodger,

Basic estimated costing for the Noble Discoverer crane replacement would be as follows (inclusive of estimated yard costs):

$4.4MM	Purchase 2x Liebherr MTC-1900-50 pedestal cranes
$0.5MM	Shipping from Austria to Seattle
$1.5MM	Removal of 2x existing cranes and pedestals
$2.0MM	Fabricate and install 2x new pedestals
$2.0MM	Install 2x new Liebherr cranes
$10.4MM	**Estimated project cost**

The cranes as designed and built are matched for the 9408 engine. The retrofit to use another engine model will involve extensive rework of the machinery room, crane controls, and reclassification.

Regards,

Garth

Garth Pulkkinen
Operations Manager - Alaska
Noble Drilling (U.S.) LLC
188 W. Northern Lights Blvd.
Suite 620
Anchorage, AK 99503
TEL: +1-907-433-7417
MOB: +1-832-235-4332
FAX: +1-281-596-4462
E-mail: gpulkkinen@noblecorp.com

Ronnie,
There is not any engine OEM in the world that builds a Tier 4 Interim engine with water cooled exhaust
manifolds and turbochargers.

Halliburton Technology as well as Caterpillar, Cummins, and other engine OEM's do not recommend
installing dry exhaust Tier 4 Interim engines
In off-shore equipment.

Two main reasons that everyone cites are that Tier 4 Interim engines have exhaust after treatment
systems that require 15 ppm diesel fuel which is not readily available off-shore
Around the world and more importantly the exhaust temperatures of the after treatment components get
extremely hot, hotter than during normal operation. Also, Tier 4 Interim
Engines cannot be fitted with exhaust gas coolers, such as Pyroban coolers, etc… and they cannot be
operated in hazardous areas.

We hope this provides some in-site into a few of the reasons tier 4 interim is not recommended for off-
shore use.

Regards,

Billy Coskrey, P.E.
Halliburton Technology
Heavy Equipment Components & Standards
2600 S 2nd St Duncan, OK 73536-0445
Office Phone: 580-251-3752
Fax: 580-251-3008

APR 2 5 2011

Mr. Gregg Ammon
Environmental Manager
1111 S 103rd St.
Omaha, NE 68124

RE: Request for a Determination 40 C.F.R. 63 Subpart ZZZZ - National Emission Standards
      for Hazardous Air Pollutants for Reciprocating Internal Combustion Engines

Dear Mr. Ammon:

Thank you for your inquiry regarding the National Emission Standards for Hazardous Air
Pollutants (NESHAP) for Spark Ignition (SI) Reciprocating Internal Combustion Engines
(RICE) as promulgated August 20, 2010. In your letter sent to the Environmental Protection
Agency (EPA) Region 7, March 3, 2011, Northern Natural Gas is seeking clarification of 40
C.F.R. §63.6625 (h) which states,

> (h) If you operate a new, reconstructed, or existing stationary engine, you must minimize the
> engine's time spent at idle during startup and minimize the engine's startup time to a period
> needed for appropriate and safe loading of the engine, not to exceed 30 minutes, **after which
> time** (bold added) the emission standards applicable to all times other than startup in Tables
> 1a, 2a, 2c, and 2d to this subpart apply.

Accordingly, Tables 1a, 2a, 2c, and 2d lists requirements for new, reconstructed, and
existing RICE at major and area sources of HAP. In the tables, each requirement for each engine
type is specified to apply outside of periods of startup, "You must meet the following
requirement, except during periods of startup..." Each table then specifies that "During periods
of startup you must..."

> Minimize the engine's time spent at idle and minimize the engine's startup time at startup to a
> period needed for appropriate and safe loading of the engine, not to exceed 30 minutes, **after
> which time the non-startup emission limitations apply** (bold added).[1]

Engine startup is defined in the definitions section of the RICE NESHAP, 40 C.F.R. §63.6670.

> *Engine startup* means the time from initial start until applied load and engine and associated
> equipment reaches steady state or normal operation. For stationary engine with catalytic
> controls, engine startup means the time from initial start until applied load and engine and
> associated equipment, including the catalyst, reaches steady state or normal operation.

---

[1]Sources can petition the Administrator pursuant to the requirements of 40 CFR 63.6(g) for alternative work
practices. Area sources can work with their permitting authority to establish alternative work practices.

RECYCLED

In consultation with EPA Office of Air Quality Planning and Standards (OAQPS), Office of General Counsel (OGC), and Office of Compliance (OC), EPA reads the 30 minute limit for engine startup as referenced in Tables 1a, 2a, 2c, 2d, and 40 C.F.R. §63.6625 (h) to not exclude startup operations beyond the 30 minute limit. Instead, the 30 minutes of startup is a period when the numerical emission limitations under normal operation do not apply. For example, an existing non-emergency, non-black start 2 stroke lean burn (SLB) stationary RICE greater than or equal to100 horsepower (HP) but less than 500 HP at a major source for HAPs, must limit concentration of carbon monoxide (CO) in the stationary RICE exhaust to 225 parts per million, volumetric dry (ppmvd) or less at 15 percent oxygen. During startup, the 2SLB engine does not have to limit CO exhaust to 225 ppmvd. After 30 minutes of engine startup, the standard applies and compliance is determined over the course of 3-hour block averages of all recorded readings. See 40 C.F.R. §63.6625.

In some cases, temperature readings at the inlet of the catalyst are used to ensure a percent of emissions reduced across the catalyst is being met. The readings are averaged over 4-hours on an hourly rolling basis. See Table 6 in the NESHAP for RICE. The 30 minutes of engine startup are also excluded from any 4-hour rolling averaging period of temperature readings to determine compliance.

EPA believes this 3-hour or 4-hour averaging period is suitable to determine compliance for each engine standard since some conditions may arise where an engine cannot instantaneously meet an emission limit, such as immediately following 30 minutes of startup or during every second of operation thereafter. See *Response to Public Comments on Proposed National Emission Standards for Hazardous Air Pollutants for Existing Stationary Reciprocating Internal Combustion Engines Located at Area Sources of Hazardous Air Pollutant Emissions or Have a Site Rating Less Than or Equal to 500 Brake HP Located at Major Sources of Hazardous Air Pollutant Emissions-Memorandum* dated August 10, 2010, Response to Comment 3.4,

> EPA is not finalizing numerical emission standards in the final rule for periods of startup. For the emission standards that are applicable during other operations, EPA has clarified that the standards are based on the average of three 1-hour runs. This provides an adequate averaging period for compliance demonstrations during periods other than startup.

As you point out, there may be instances where an engine cannot achieve certain parameters (i.e. inlet temperature) within 30 minutes of starting up. You suggest that the engine would need to shut down and ask whether there are any restrictions in the rule for initiating another startup subsequently. As discussed above, the regulations do not require that the engine shut off if it does not complete startup within 30 minutes, only that after 30 minutes any further activity would be counted as part of normal operation. Regarding multiple startups, in general, startup times should be considered as separate occurrences and are allowed 30 minutes per event. Startups that occur consecutively with short durations between could be considered one startup event since the startups are part of a single occasion where the engine is working up to steady state or normal operations.

Keep in mind there are general duty provisions in the Clean Air Act, 40 C.F.R. Part 63, and RICE NESHAP to operate "...in a manner consistent with safety and good air pollution control practices for minimizing emissions," 40 C.F.R. §63.6605.

If you have any additional questions, please contact Eric Sturm at 913.551.7377 or sturm.eric@epa.gov.

Sincerely,

Leslye Ewerman

for Mark A. Smith
Branch Chief
Air Permitting and Compliance
U. S. Environmental Protection Agency, R7

cc: Michael Horowitz, EPA Office of General Counsel
Melanie King, EPA Office of Air Quality Planning and Standards
John Dupree, EPA Office of Compliance

Process for Determining the Cause Category for Each 15-minute Deviation

- 15-minute data was extracted from the database for each generator engine while the Discoverer operated as an OCS Source.
- The data was then run through a set of conditions to determine when temperature and/or urea deviations occurred.
- After all deviations were identified, the operational data for each 15-minute period was analyzed to determine what caused the deviation.
- Instructions on how to read the figures have been provided below along with an example determination.

Instructions for reading the figures:

- All three plots on each figure show data on a 5-minute basis.
- Each figure provides an example of a type of operational data that was extracted from the database.
  - (S) – Engine start-up/shutdown
  - (L) – Low engine load
  - (O) – Engine off, spurious data
  - (E) – Equipment malfunction
  - (R) – Previously submitted deviation reports
- The first plot on each figure shows urea flow in gal/hour. The scale is on the left hand side.
- The second plot on each figure shows electrical output in kW-e. The scale is on the left hand side.
- The third plot on each figure has multiple added features.
  - The fuel flow rate in gal/hour is represented by the black dots connected with a black line. The scale for fuel flow is on the left hand side.
  - The stack temperature in degrees Centigrade (^{o}C) is represented by the blue line. The scale is on the right hand side.
    - When the temperature line is colored red, it indicates that the exhaust temperature is below 300 ^{o}C.
    - When the line is thick and blue, it indicates that there is no urea flow while the engine is operating.

S   **Engine start-up / shut down.** Temperatures or loads during start up and shut down periods were below minimums required in the permit or were below minimums required for urea dosing.
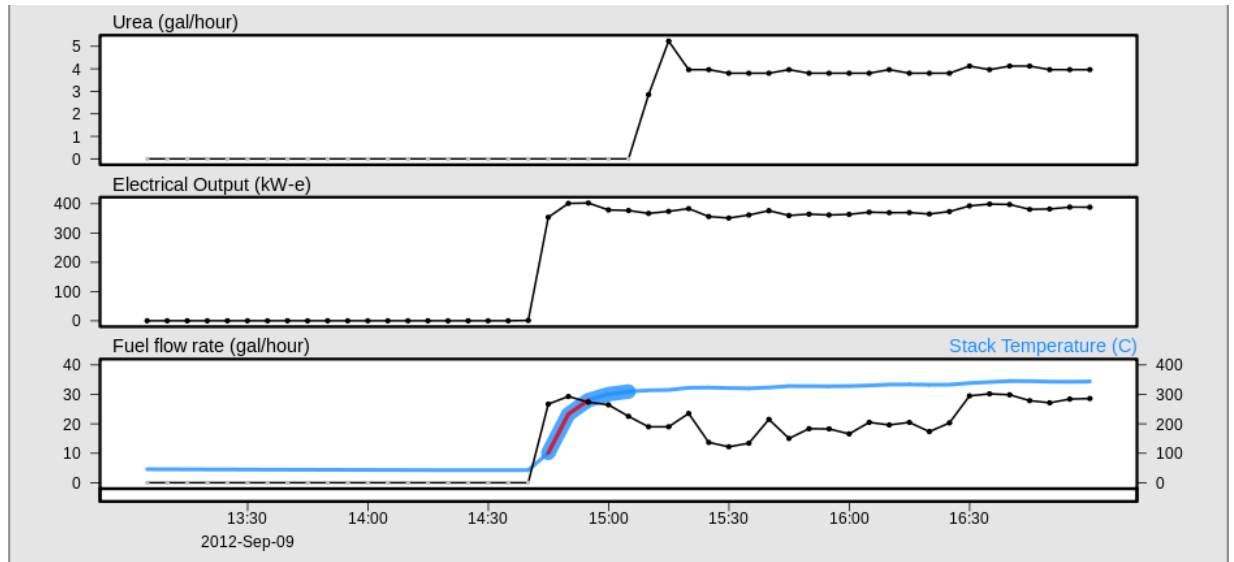
Figure 1. FD-1 on 9/9/2012

Figure 1 demonstrates an example of when start up conditions result in a deviation from permit condition requirements. The urea flow, electrical output, fuel flow, and stack temperature from 13:00 to 14:40 indicate that the engine is off. At 14:45, the electrical output, fuel flow, and rising stack temperature indicate that the engine has been turned on. At this point, the urea flow has not started because the stack temperature has not met the minimum temperature threshold needed to initiate urea dosing. At 15:10, the stack temperature has reached the minimum threshold needed to activate urea flow. After 15:10, the engine is operating under controlled emission conditions.

L   **Low engine load.** Low engine load generally produces lower exhaust temperature and in some cases, causes urea dosing to cease.

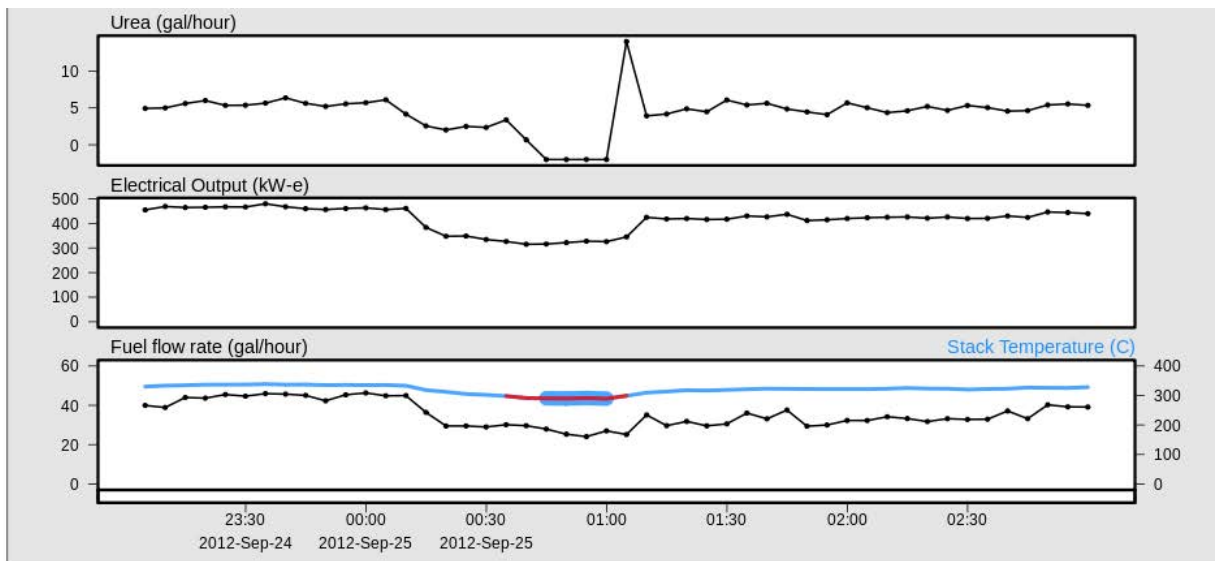**Figure 2. FD-2 on 9/24/2012 and 9/25/2012**

Figure 2 demonstrates an example of when low engine loading results in a deviation from permit condition requirements. From 23:00 to 00:10, the engine is operating under controlled emission conditions. At 00:10, the fuel flow and electrical output decrease. As a result, the stack temperature begins to decrease due to reduced engine loading. The engine is still operating under controlled emission conditions at this time. The stack temperature continues to decline while the engine load is reduced. At 00:30 the stack temperature drops below 300 ^{o}C resulting in a deviation from a permit condition requirement.   At close to 300 ^{o}C the E-POD controller shuts down the urea flow as designed. At approximately 00:55, the engine load increases and the stack temperature begins to rise. The E-POD controller restarts urea dosing shortly after 01:00 when adequate minimum temperature is achieved. At 01:05, the engine is operating under controlled emission conditions.

It should be noted that the 15-minute reporting period from 01:00 to 01:15 was not a deviation because the engine was operating under controlled emission conditions for at least two of the three 5-minute periods within the 15-minute period.

O   **Engine off, spurious data**. Due to vibration or pulsations in the fuel flow lines, the metering system will sometimes record short spikes in fuel usage or electrical output when the corresponding engine is clearly off (typically indicated by a steadily decreasing or flat line temperature).
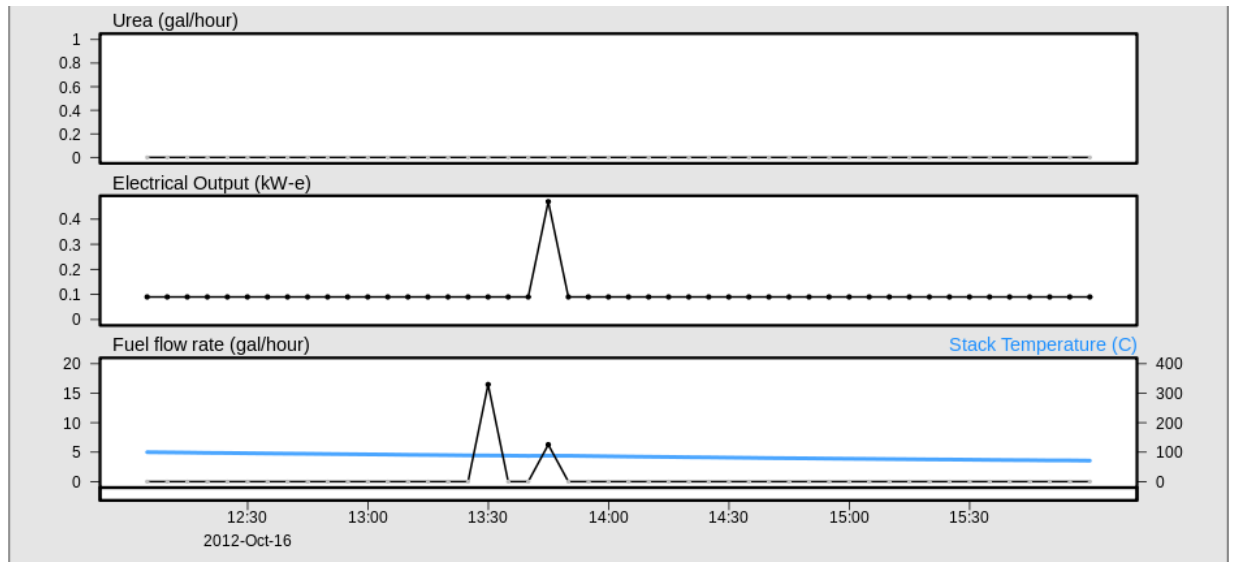
Figure 3. FD-2 on 10/16/2012

Figure 3 demonstrates an example of when the analogue meters register spurious data when the engine is clearly off. In this case, the fuel flow spikes to about 15 gal/hour at 13:30 with no reading for electrical output and the stack temperature is trending down during the same time period. This type of event occurs again at 13:45 when the fuel flow jumps above 5 gal/hour. This time, electrical output registered a corresponding spike in fuel, but the electrical output reading is virtually 0 (approximately 0.4 kW-e). During this second period, the stack temperature continues to trend down. This evidence supports that the engine is off during this time and that the data recorded here is spurious.

E   **Equipment malfunction.** An example is loss of temperature sensor reading.
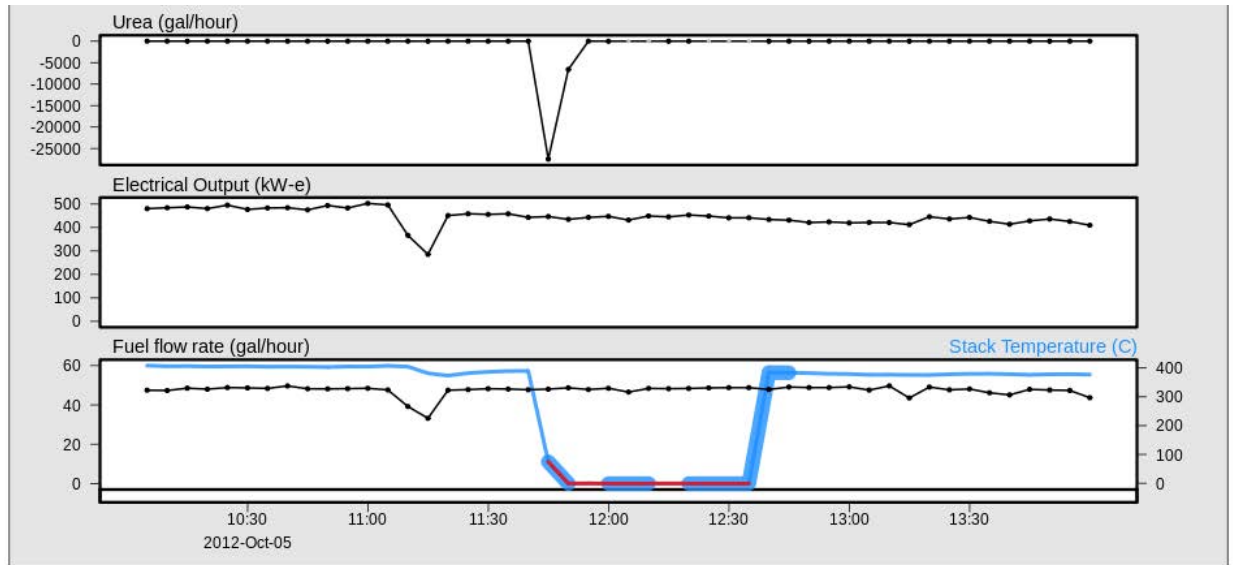
Figure 4. FD-6 on 10/5/2012

Figure 3 demonstrates an example of when an equipment failure leads to a deviation from permit condition requirements. Starting at 10:00, the engine is operating under controlled emission conditions. At 11:45, there was a loss of communication with the exhaust temperature probe associated with this engine. Due to the lack of communication, the stack temperature is registered as 0 ^{o}C. This lack of temperature communication triggers the E-POD controller mechanism to turn off the urea dosing. Once communication with the temperature probe was reestablished, the correct stack temperature is registered and urea dosing resumes.

R   **Refer to previously submitted Emission Deviation Report** for this date and source. An example here is the impact of maintenance work on the Discoverer E-PODs on September 22, 2012.

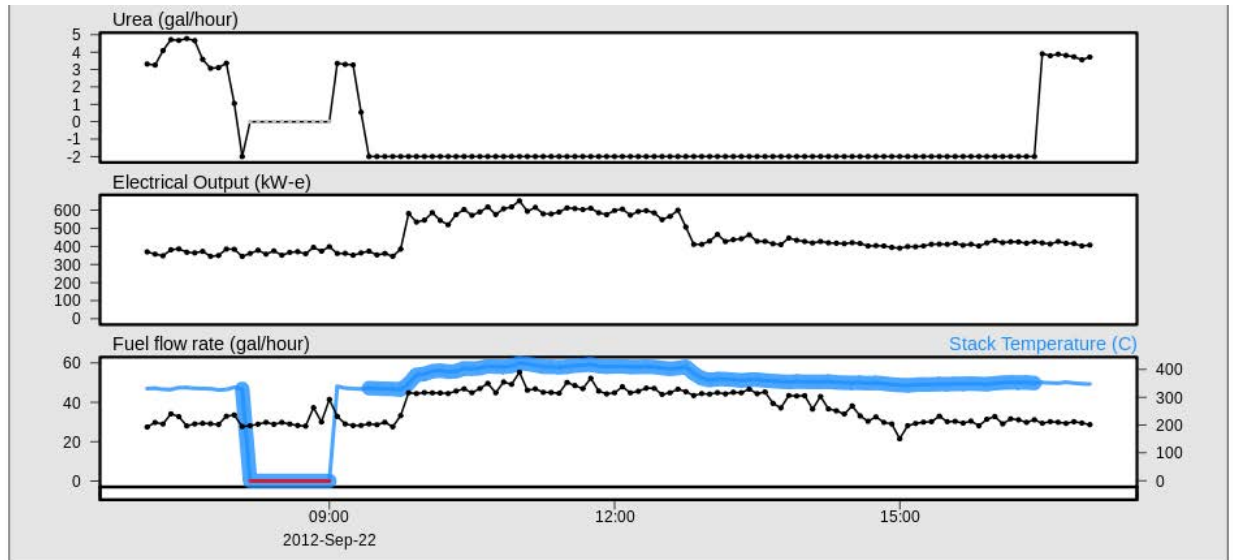**Figure 5. FD-1 on 9/22/2012**

Figure 5 shows an example of data that was previously submitted to the EPA in an Emission Deviation Report. This period of time includes when maintenance was performed on the Discoverer's E-PODs on September 22nd. Due to the nature of the maintenance required, the E-POD was unable to continuously record stack temperature and urea flow for various periods.

A number of minor inconsistencies were discovered between the application text and the modeling files. After correcting these inconsistencies, ENVIRON reran the modeling. There were no substantive changes in the modeling results. The revised modeling appendix (Appendix D of the November 29 permit application) is attached in "marked text" and "changes accepted" formats. Following is a brief explanation of the changes made that are reflected in the revised modeling appendix.

1. Page D-9 of the text and Table D-3 of the November 29 application request a revision in the daily PM2.5 emission limit from the current 75.09 lb/day to 52.55 lb/day. The modeling was conducted assuming 48.80 lb/day, but the text and Table D-3 were not changed to match the modeling.   The text was revised to reflect the correct emission limit (48.8 lb/day).

2. The way in which supply ship fuel consumption was calculated was changed by increasing the fuel used during the time the ship is sufficiently close to the Discoverer to include its emissions in the modeling.

3. Table D-4 of the November 29 application showed total emissions of CO and SO2 for the resupply ship while in transit mode, rather than just showing the portion which was modeled. While not an error, it is more correct and more consistent with the other pollutants to show the CO and SO2 emissions using the same calculation method as was done for NOx.   CO and SO2 emissions were decreased in Table D-4 to reflect this.

4. CO and SO2 emissions from the incinerators on the ice breaker, the anchor handler and the OSR Main ship were not included in the modeling submitted with the November 29 application. They were added in for this latest revision.

5. Modeling of annual-average NOx concentrations in the November 29 application was performed by scaling the short-term model runs using the ratio of long-term to short-term emission rates. Because the NOx modeling used the PVMRM algorithm, which is non-linear with emission rate, for the revised modeling it was more appropriate to calculate annual-average concentrations using separate runs with annual-average emission rates.

6. The November 29 application reported modeling results in Table D-5. The modeling results for 1-hour NOx were based on the emission rates shown in Table D-4 except that emissions from cementing engines in the model runs were 13.86 lb/hr, not the 11.60 lb/hr shown in the Table. To be consistent with the permit application request, the revised model results have been based on an hourly NOx emission rate of 11.6 pounds for the cementing engines.

7. One element of the modeling provided in the November 29 application warrants further explanation. The modeling provides a conservative assessment of annual impacts because it models an hourly emission rate that is higher than the permitted hourly emission rate. The modeling takes this approach because the November 29 application requests a prohibition on using the Discoverer incinerator when the resupply ship operates in DP mode adjacent to the Discoverer. To be conservative, the 2011 air quality modeling assumed 600 hours of incinerator operation per drilling season (5 hours of operation/day for 120 days). Incorporating the requested restriction preventing incinerator operation during resupply visits, the number of hours of incinerator operation assumed in the modeling drops from 600 to 480 per drilling season if 24 supply trips are assumed. This is because while the restriction has no effect on maximum hourly or maximum daily emission rates, with fewer hours of incinerator operation, the restriction could reduce annual emissions if the supply ship were to come as often as

modeled. So, to accommodate the current annual emission limit in the air quality modeling, the hourly emission rate was increased for each of the 480 hours in the model runs so that the total would match the current permit annual emission limit.

In addition to the changes detailed above, you will note the modeling files include a combined and much more comprehensive emission spreadsheet that provides a complete link between the emission calculations and assumptions and the actual model-input values used in each run. Additionally, ENVIRON has prepared a model-results summary spreadsheet that tracks to the model results table in the report.

Air Quality Modeling Analysis for Shell November 29, 2012 Permit Application and Subsequent Additional Modeling Submittal

The following flow chart details the process used in performing the air quality modeling for the Shell Off-shore Drilling Operation Permit application Modification, submitted on November 29. 2012 and later supplemented with additional model runs. Figure 1 is a schematic flow chart that documents the modeling process used.

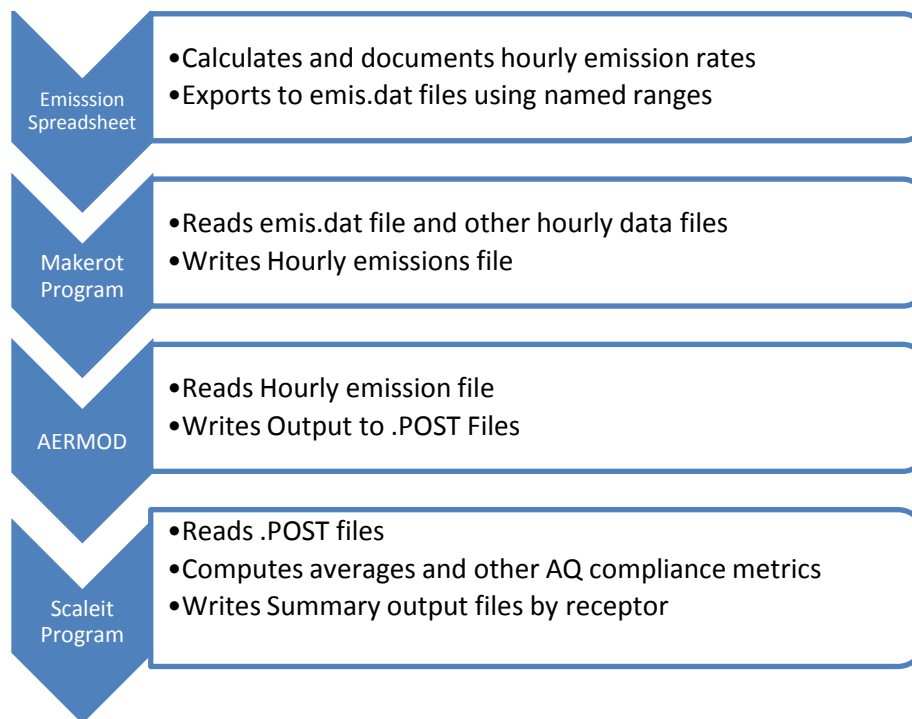| Emisssion Spreadsheet | • Calculates and documents hourly emission rates
• Exports to emis.dat files using named ranges |
Makerot Program	• Reads emis.dat file and other hourly data files • Writes Hourly emissions file
AERMOD	• Reads Hourly emission file • Writes Output to .POST Files
Scaleit Program	• Reads .POST files • Computes averages and other AQ compliance metrics • Writes Summary output files by receptor

Figure 1. Modeling Process Flow Diagram

The enclosed computer flash drive contains the modeling files including the large emission.xlsx spreadsheet. The spreadsheet contains a series of worksheets that each addresses a different subject. There are 16 model-defined emission sources. The purpose of this spreadsheet is to document how the emission rates for each model-identified emission source were calculated and to show how these emissions were prepared for input to the AERMOD model.   The following bullets describe each worksheet and its associated function:

- **NOx Emissions.** This worksheet details the calculations of the NOx emission rates used in the air quality modeling. For NOx, information is provided for both start-up emissions and normal emissions.
- **PM2.5 Emissions.** This worksheet details the calculation of the PM2.5 emission rates used in the air quality modeling
- **PM10 Emissions.** This worksheet details the calculation of the PM10 emission rates used in the air quality modeling

- **CO Emissions.** This worksheet details the calculation of the CO emission rates used in the air quality modeling
- **SO2 Emissions.** This worksheet details the calculation of the SO_2 emission rates used in the air quality modeling
- **NOx 2009 Seq A emissions.** This worksheet shows how the maximum hourly emissions of NOx for each of the 16 model-identified sources was turned on and off for each hour of the full 2009 year under Sequence A. Within this worksheet is a named range of cells called "NOxSeqA2009Hourly" which is the product of the spreadsheet and is copied to a file called emis.dat in the directory for this pollutant, year, sequence and averaging time.
- **NOx 2009 Seq B emissions.** This worksheet shows how the maximum hourly emissions of NOx for each of the 16 model-identified sources was turned on and off for each hour of the full 2009 year under Sequence B. Within this worksheet is a named range of cells called "NOxSeqB2009Hourly" which is the product of the spreadsheet and is copied to a file called emis.dat in the directory for this pollutant, year, sequence and averaging time.
- **NOx SeqA Annual emissions.** This worksheet shows how the annual-average emissions of NOx for each of the 16 model-identified sources was turned on and off for each hour of the full 2009 year under Sequence A. Within this worksheet is a named range of cells called "NOxSeqA2009Annual" which is the product of the spreadsheet and is copied to a file called emis.dat in the directory for this pollutant, year, sequence and averaging time.
- **NOx SeqB Annual emissions.** This worksheet shows how the annual-average emissions of NOx for each of the 16 model-identified sources was turned on and off for each hour of the full 2009 year under Sequence B. Within this worksheet is a named range of cells called "NOxSeqB2009Annual" which is the product of the spreadsheet and is copied to a file called emis.dat in the directory for this pollutant, year, sequence and averaging time.
- **PM2.5 2009 SeqA.** This worksheet shows the hourly emissions of PM2.5 are assigned for each hour of the 3,672 potential drilling season hours (July 1 – Nov 30) under Sequence A for 2009.
- **PM2.5 2009 SeqB.** This worksheet shows the hourly emissions of PM2.5 are assigned for each hour of the 3,672 potential drilling season hours (July 1 – Nov 30) under Sequence B for 2009.
- **PM2.5 2010 SeqA.** This worksheet shows the hourly emissions of PM2.5 are assigned for each hour of the 3,672 potential drilling season hours (July 1 – Nov 30) under Sequence A for 2010.
- **PM2.5 2010 SeqB.** This worksheet shows the hourly emissions of PM2.5 are assigned for each hour of the 3,672 potential drilling season hours (July 1 – Nov 30) under Sequence B for 2010.
- **PM10 2009 SeqA.** This worksheet shows the hourly emissions of PM10 are assigned for each hour of the 3,672 potential drilling season hours (July 1 – Nov 30) under Sequence A for 2009.
- **PM10 2009 SeqB.** This worksheet shows the hourly emissions of PM10 are assigned for each hour of the 3,672 potential drilling season hours (July 1 – Nov 30) under Sequence B for 2009.
- **PM10 2010 SeqA.** This worksheet shows the hourly emissions of PM10 are assigned for each hour of the 3,672 potential drilling season hours (July 1 – Nov 30) under Sequence A for 2010.
- **PM10 2010 SeqB.** This worksheet shows the hourly emissions of PM10 are assigned for each hour of the 3,672 potential drilling season hours (July 1 – Nov 30) under Sequence B for 2010.

- **CO 2009 SeqA Ratios.** This worksheet shows the emission ratios (to 1.0 g/s) for CO under Sequence A for 2009.
- **CO 2009 SeqB Ratios.** This worksheet shows the emission ratios (to 1.0 g/s) for CO under Sequence B for 2009.
- **CO 2010 SeqA Ratios.** This worksheet shows the emission ratios (to 1.0 g/s) for CO under Sequence A for 2010.
- **CO 2010 SeqB Ratios.** This worksheet shows the emission ratios (to 1.0 g/s) for CO under Sequence B for 2010.
- **SO2 2009 SeqA Ratios.** This worksheet shows the emission ratios (to 1.0 g/s) for SO2 under Sequence A for 2009.
- **SO2 2009 SeqB Ratios.** This worksheet shows the emission ratios (to 1.0 g/s) for SO2 under Sequence B for 2009.
- **SO2 2010 SeqA Ratios.** This worksheet shows the emission ratios (to 1.0 g/s) for SO2 under Sequence A for 2010.
- **SO2 2010 SeqB Ratios.** This worksheet shows the emission ratios (to 1.0 g/s) for SO2 under Sequence B for 2010.
- **Unit 2009 SeqA.** This worksheet shows emissions for 1.0 g/s for each source in Sequence A in 2009.
- **Unit 2009 SeqB.** This worksheet shows emissions for 1.0 g/s for each source in Sequence B in 2009.
- **Unit 2010 SeqA.** This worksheet shows emissions for 1.0 g/s for each source in Sequence A in 2010.
- **Unit 2010 SeqB.** This worksheet shows emissions for 1.0 g/s for each source in Sequence B in 2010.
- **Modeled Emissions.** This worksheet is mainly for checking to make sure emission used in the actual modeling match the reported emission rates.
- **AppendixD tables.** This worksheet contains the emission tables that appear in Appendix D, specifically Table D-3 and Table D-4.
- **Sept 2011 Permit.** This worksheet has a full copy of the current air quality permit with columns added to the left to extract hard numbers from the permit. These hard numbers are referred to in other worksheets when a permit limit is referenced.
- **Flow Chart.** This worksheet has the flow chart in Figure 1 above.

The exported named ranges from the emissions.xlsx spreadsheet are each placed in different copies of files called emis.dat in the various directories which contain the model runs themselves. The directories are organized by pollutant, year, sequence and in some cases, averaging time. In each directory, a slightly different version of the makerot program, a FORTRAN program designed to write an hourly emission file from the emis.dat spreadsheet output, is found. The output from the program is a large hourly emissions file with names such as HOUREM2009A.DAT. The large size of these files is necessitated because there are 360 versions of each emission source, since the emission sources rotate about the drill hole when the wind changes and the Discoverer and supporting fleet align themselves in

a specific orientation with the wind. The makerot program reads the meteorological data file for each hour and calculates which of the 360 versions of each emission source is representative of the wind direction for that hour. The other 359 versions of the emission source are all assigned emission rates of zero for that hour.

As a result, of there being 360 versions of each emission source, there are 5,760 separate emission sources in the model, although only 16 of them are active in any given hour. With 5,760 sources and 8,760 hours for NOx, there are over 50 million emission rates which must be specified in the hourly emission file. This is the reason the hourly emission files for each NOx model run are over 3 GB in size.

Once the hourly emission file is created, the runs of AERMOD are can be made. Results are written into large post-processor files by emission source group. Each of the 360 versions of the emission source is combined into a single model-identified source group and the post-processing files have just the results from each source group.

The final step in the process is the post-processing. The main tool for post processing is another FORTRAN program called scaleit, although there are different versions of scaleit and the one used for some pollutants is called scaleit2. As a means of speeding up processing time, before scaleit is run for NOx, the year-long post-processor files are first reduced by a third FORTRAN program, called skipit. The skipit program is simple and just extracts the values for the 120-day drilling period in the sequence in question from the .POST file and writes these into a file with a .DAT extension. This was not necessary for any of the pollutants except NOx because the current version of AERMOD requires a full year of meteorological data for NOx processing. The other pollutants don't have this requirement, so the runs could be performed for just the 120 day modeling sequence and the post-processor files did not need to be extracted.

The scaleit program could be used to scale emissions to consider alternate emission scenarios and was in fact used in this fashion for CO and SO2, since these pollutants were run in a normalized (chi over Q) mode. But in fact other than for SO2 and CO, there was no scaling performed with the scaleit program. Instead the scaleit program was used to find the appropriate compliance metric for each case. For 1-hour NOx, this was to find the 8th highest daily maximum concentration for each sequence. For annual NOx, the highest of the annual averages at any receptor was found. For PM2.5 and PM10, the 2nd highest 24-hour concentration was determined at each receptor and compared to the PSD increment. For NAAQS compliance, the additional step was taken of finding the maximum value for each year at each receptor from the two sequences. The two maximum values at each receptor, one for 2009 and one for 2010 were then averaged, receptor-by-receptor, and the highest of these values added to the background concentration to compare with the NAAQS.

All necessary modeling and processing files are contained on the flash drive and should provide full documentation on the air quality modeling analysis that was performed.

Kirk Winges, 425-412-1813, December 13, 2012.

Shell Gulf of Mexico Inc.
Noble Discoverer Chukchi Sea Application to Revise OCS PSD Permit

January 11, 2013 Supplemental Permit Revision Application Information

The files listed below are not online but are available upon request to:

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1. Discoverer2012-MainGenDeviations.xlsx
2. RS Nanuq Emissions 20120806.xlsx
3. CMS Compliance Monitoring Disco_FD-14_FD-17_2.xlsx
4. Discoverer Main Generator Data.xlsx
5. Discoverer Main Generator Data-analysis.xlsx
6. 2012-09-DiscoTempUreaDevFullData_r1-FD-1-6.xlsx.xlsx
7. 2012-10-DiscoTempUreaDevFullData-FD1-6.xlsx.xlsx
8. CFDPlots.xlsx
9. Emissions.xlsx
10. ModelResultsSummary.xlsx
11. NOx2009Aannual.zip
12. NOx2009Ahourly.zip
13. NOx2009Bannual.zip
14. NOx2009Bhourly.zip
15. PM2.52009A.zip
16. PM2.52009B.zip
17. PM2.52010A.zip
18. PM2.52010B.zip
19. PM102009A.zip
20. PM102009B.zip
21. PM102010A.zip
22. PM102010B.zip
23. Unit2009A.zip
24. Unit2009B.zip
25. Unit2010A.zip
26. Unit2010B.zip